Land Cover and Agricultural Management Definition within the Upper Wisconsin River Basin

July 11, 2014
Developed in support of the
Wisconsin River Total Maximum Daily Load Study
Bureau of Water Quality
Wisconsin Department of Natural Resources

Revision History

- 2015-02-05:
    - An error was found in the tables contained in Appendix C, Generalized Rotations by Name and Code. All fertilizer applications were reported in units of kg/acre. The values in the table were actually those calculated in units of kg/ha. All units were changed to kg/ha.

Disclaimer

This document was developed by the Wisconsin Department of Natural Resources and represents the landcover and agricultural management inputs that will be integrated into the watershed model supporting TMDL development in the Wisconsin River Basin. The inputs are subject to change as a result of model calibration and/or improved conceptualization. Questions regarding this document or the Wisconsin River TMDL project should be directed to dnrwisconsinrivertmdl@wisconsin.gov.

Acronyms and Terminology

CDL – The Cropland Data Layer is derived from satellite imagery and provides acreage estimates to the Agricultural Statistics Board for the state's major commodities as well as digital, crop-specific, categorized geo-referenced output products. The CDL is a product of the US Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS).

CDL Rotation – The Cropland Data Layer rotation coverage is a static landcover of rotation types that was created from the Cropland Data Layer years 2008-2012 using a decision tree rule set that catenated the individual years to create generalized rotation categories based on crop sequences.

CLU – The Common Land Unit is the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer in agricultural land associated with USDA farm programs. CLU boundaries are delineated from relatively permanent features such as fence lines, roads, and/or waterways.

CRP – The Conservation Reserve Program is a land conservation program administered by the Farm Service Agency (FSA). Enrolled farmers receive a rental payment in exchange for removing environmentally sensitive land from production on 10-15 year contracts.

DATCP – Wisconsin Department of Agriculture, Trade and Consumer Protection

HRU – Hydrologic Response Units are portions of a subbasin that possess unique land use, management, and soil attributes. It is the total area within a subbasin with a particular combination of land use/management/soils, not a specific parcel or field.

LWCD – Land and Water Conservation Department - County level conservation offices

NASS – The National Agricultural Statistics Service is a division of the United States Department of Agriculture and provides timely, accurate, and useful statistics to U.S. Agriculture.

NLCD – The National Land Cover Database is a Landsat derived land cover classification product created by the Multi-Resolution Land Characteristics (MRCL) consortium.

NMP – Nutrient Management Plan

NRCS – Natural Resources Conservation Service

PLSS - Public Land Survey System

SWAT – Soil and Water Assessment Tool

TMDL – Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards.

Transect Survey – A predefined route through a county that is driven by county staff each year to observe and document agricultural land management and land cover.

USDA – United States Department of Agriculture

USDA-ARS – United States Department of Agriculture Agricultural Research Service

WDNR – Wisconsin Department of Natural Resources

WDNR Approach – The Wisconsin Department of Natural Resources methodology of defining six year crop rotations using a combination of land cover products coupled with local knowledge of land management.

WRB – Wisconsin River Basin is the extent of the Upper Wisconsin River Basin from Lake Wisconsin to the headwaters in northern Vilas County.

WWI – Wisconsin Wetlands Inventory is the Wisconsin Department of Natural Resources’ wetlands mapping product.

1.0 Overview

The Upper Wisconsin River Basin (WRB) drains 9,156 mi^2 of land from the headwaters in Vilas County to Lake Wisconsin in Columbia and Sauk Counties. Numerous water bodies within the WRB are currently listed on the state and federal Sec. 303(d) impaired waters list due to degraded habitat, algal problems, or eutrophication. The dominant causes of the algae blooms are excessive phosphorus loading from end-of-pipe point and diffuse nonpoint sources in the watershed. Because the Wisconsin River system is an important recreational, industrial, and natural resource to the State of Wisconsin there is a need to identify nutrient loading sources and environmental conditions causing impaired water quality and to develop decision-making capabilities for improving these conditions. As a result, a comprehensive study of the WRB has been initiated by the Wisconsin Department of Natural Resources (WDNR) that will culminate in the development of a plan to improve the water quality of the river, its impoundments and tributaries. The comprehensive study relies on the Total Maximum Daily Load (TMDL) framework, which defines the amount of a pollutant (phosphorus) that can be discharged into a waterway and still meet water quality standards. The TMDL assesses the watershed for pollutant loads from the various sources in the watershed including municipal and industrial effluent, urban stormwater, agricultural runoff, and background contributions from natural sources. In conjunction with a four year monitoring study, a modeled approach will be used to simulate upland loading, transport of sediment and nutrient loads, and in-reservoir or in-lake process for waters including (but not limited to) Spirit Flowage, Big Eau Pleine Reservoir, Lake DuBay, Dexter Lake, Tri-Lakes, Petenwell and Castle Rock flowages, and Lake Wisconsin.

The development of a TMDL requires understanding and definition of the entire system affecting an impaired water body. To assess the WRB watershed for pollutant loads from the various sources a watershed response model called the Soil and Water Assessment Tool (SWAT) will be used to simulate flow and water quality conditions throughout the entire WRB TMDL study area for twelve years (2002 - 2013). The SWAT model is an open source, distributed, continuous daily time-step, geographic information system (GIS) based model developed by the U.S. Department of Agriculture - Agriculture Research Service (USDA-ARS) for the prediction and simulation of discharge, total suspended solids (TSS), and nutrient yields from mixed landuse watersheds (Nietsch et al., 2005). The SWAT model incorporates the effects of climate, surface runoff, evapotranspiration, crop growth, groundwater flow, nutrient loading, and water routing for different land uses and land management practices to predict hydrologic response. SWAT divides a large watershed into subwatersheds, which are further subdivided into hydrologic response units (HRUs) which are defined as unique combinations of soil, land cover type, and management practices in a subwatershed. SWAT simulates hydrology, vegetation growth, and management practices at the HRU level. The ability for SWAT to simulate each of the aforementioned processes and properly define the distribution of nutrient sources can be improved with spatial and temporal representative model inputs such as land cover and management.

Land cover and land management datasets are two of the datasets integrated into the SWAT model to develop TMDL’s in the WRB (WDNR, 2013). Land cover and land management are diverse across the 9,156 mi^2 WRB yet both are critical for quantifying the hydrologic and nutrient budget. The purpose of this technical memorandum is to describe the approach that the WDNR used to develop the land cover and agricultural land management components that were applied to the SWAT model in support of the development of TMDLs in the WRB.

2.0 Land Cover Definition

2.1 Overview

One of the principal datasets for simulating hydrologic and nutrient response from the landscape using SWAT is the land cover. Land cover provides the SWAT model with a distribution of a defined land use which is linked to hydrologic, erosion, and ecological SWAT model parameters. When combined with soil, slope, and management, land cover is a key element in simulating subwatershed processes and subsequent nutrient sources through the model's HRUs. The objective in developing the land cover dataset for the WRB TMDL was to use the best available information to create a refined static snapshot of conditions that appropriately captured the basins heterogeneity and represented average conditions from 2002 to 2013 while supporting the requirements of the TMDL.

2.2 Methodology

The composite land cover developed for the SWAT model input began with the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) 2011 Cropland Data Layer (CDL) for Wisconsin. The layer, originally created to provide agricultural information for the major crops to the USDA Agricultural Statistics Boards, provides a raster-based, geo-referenced data layer that defines growing season land cover at the 30x30m pixel for Wisconsin using satellite imagery from a variety of satellites (USDA, 2011). For non-agricultural land cover, the USDA NASS CDL relies on the United States Geological Survey (USGS) National Land Cover Database (NLCD) 2006. The 2011 USDA NASS CDL was selected because that year had improved accuracy statistics when compared to other years.

To improve the landcover definition other basin-wide information was integrated into the 2011 CDL in the following order: Wisconsin Wetlands Inventory (WWI), hand-digitized cranberry bogs, and conservation reserve program land (CRP). The WWI coverage provides the geographic extent of wetlands that have been digitized from aerial photography, verified through photo interpretation, and compared against soil surveys, topographic maps, and previous wetland inventories (WDNR 1991). The 2011 CDL was unable to properly capture the extent of cranberries due to the timing of the satellite imagery. As a result, the cranberry bog extent was digitized from the statewide Bing aerial photo basemaps (2011). The CRP land extent was captured from a 2008 USDA Common Land Unit (CLU) attribute defining land designated as CRP. While the CRP extent can change from year to year, the use of the 2008 extent provided an average condition for the simulation period.

2.3 Summary of Product

The final product shown in Figures 1 and 2 is a geospatial 30-meter raster grid that defines 12 land cover classes (agriculture, barren, cranberries, CRP, forest, grassland, shrubland, urban/developed, herbaceous wetlands, and woody wetlands) for the Upper Wisconsin River Basin. The coverage can be obtained by contacting the WDNR at dnrwisconsinrivertmdl@wisconsin.gov.

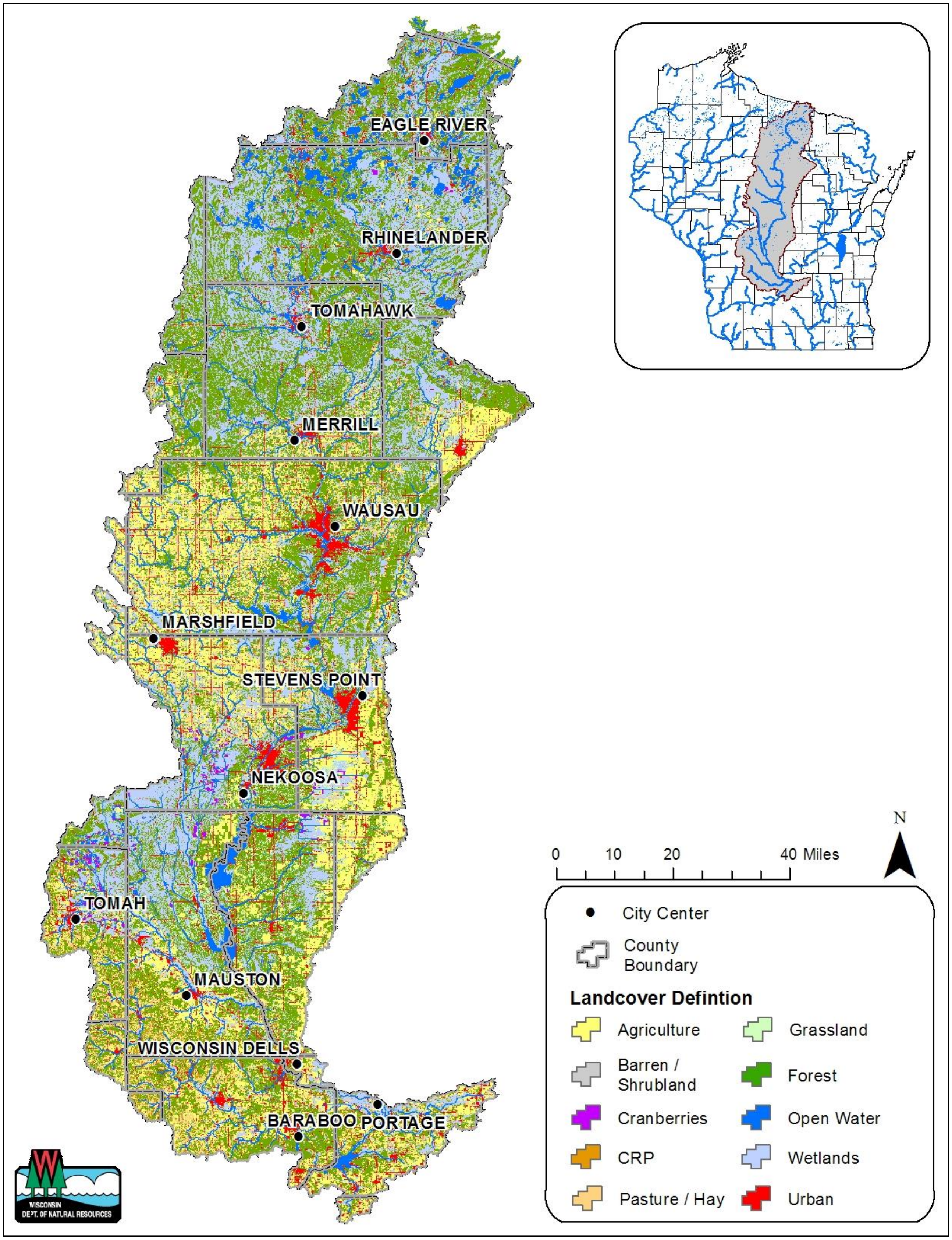


Figure 1. WRB land cover composite.

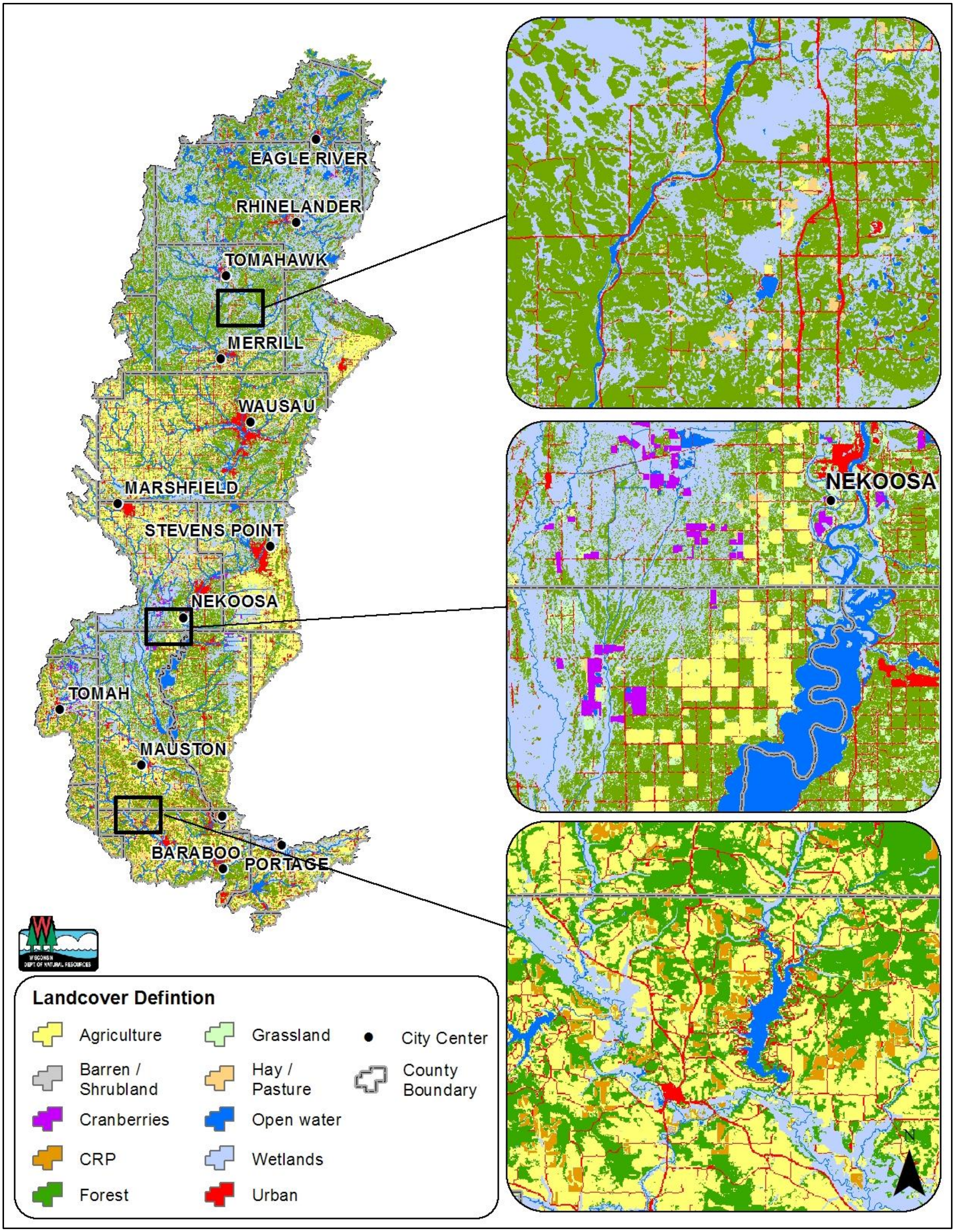


Figure 2. Focused View of Land Cover Definition.

3.0 Agricultural Land Management Definition

3.1 Overview

The representation of agriculture is particularly important in the WRB where agriculture covers nearly 25% of the 9,156 mi^2 watershed and when combined with other variables such as precipitation, soils, and slope, can be a significant contributor of sediment and phosphorus delivery to receiving waters. Although landcover data is easily accessible from remotely-sensed products, how the land is managed cannot be inferred from remote-sensing. Incorporating spatiotemporal land management information into an improved landcover classification provides further refinement when defining hydrologic and water-quality response variability. The use of the SWAT model provides the opportunity to distinguish between *land cover* and *land management*. One of SWAT's strengths, and one of the primary reasons it was selected for the WRB TMDL modeling effort, is its ability to model variability in land management on a daily time step.

The agricultural landscape throughout the WRB is heterogeneous, ranging from the dairy farming in the north central region, potato and vegetable in the central sands and corn and soybean crops in the southern region. Unique subsets of each type of farming can exist within a region creating greater diversity. The WDNR approach for defining agricultural management within the WRB incorporates a 6-year crop sequence with associated tillage, nutrient applications and other management practices such as tile drainage and w-ditches.

The objective of this effort was to develop and implement a methodology that integrates geospatial data and analysis, county Land and Water Conservation staff and local agronomist knowledge, and field-collected data such as transect surveys to define agricultural management. The methodology was applied to agricultural landcover within the WRB. The result is a spatial layer that defines spatiotemporal variability of agricultural land management, such as rotation, tillage, and nutrient application, for all 160-acre agricultural plots above Lake Wisconsin.

3.2 Methodology

The definition of agricultural land management within the WRB does not exist as readily available dataset, but rather must be developed through a series of steps. The WDNR utilized four steps towards the development of a geospatial agricultural management product:

1. Pixel based spatiotemporal crop definition within USDA CDL agricultural lands
2. Interviews with county conservationists and agricultural professionals to verify crop rotations
3. Integration of geospatial data and local knowledge
4. Validation of geospatial agricultural management product against measured data

As a result of the size of basin and the requirements of TMDL development, it was first determined that it was not necessary or realistic to collect field-scale information such as nutrient management plans or the location of feed lots, barnyards, or manure storage locations. Instead, the effort focused on spatially identifying general types of agricultural management to provide the necessary information in support of TMDL development and watershed targeting. A further assessment could then be conducted during TMDL implementation, building upon the product described in this technical memorandum.

3.2.1 CDL-Based Rotation Definition

The objective of the first step was to classify crop rotations by examining the annual change in crop classification for a specific area of interest during a five year period (2008-2012). These years were chosen due to the accuracy of the CDL during that time period. Crop sequences were originally defined by Public Land Service System (PLSS) ¼ sections (approximately 160 acres). For each year in the period, the dominant agricultural type within a specific ¼ section was applied to that ¼ section. The dominant agricultural type per ¼ section for each of the five years was concatenated together to create a crop sequence for each ¼ section for the time period (Figure 3). This analysis resulted in a five-year sequence of crop type for each ¼ section which was then classified into an agricultural rotation type based on a set of rules. The rotations were divided into the following general types: (1) Dairy Rotation, (2) Cash Grain, (3) Continuous Corn, (4) Pasture/Hay, and (5) Potato/Vegetable. Identifying the rotation type for each ¼ section's five year sequence was done by creating a hierarchical rule set that binned crop rotation types based on the presence or absence of certain crop types that were indicative of general rotation types (Appendix A). Dairy rotations, for instance, required at least one year of corn in 5 years and at least one year of alfalfa/hay. The spatially identified crop rotation types provided distinct parcels to attribute with more detailed regionally-specific and regionally-validated agricultural management data.

Due to the heterogeneity is some areas, the generalized crop rotations were further refined from the PLSS ¼ section to the Common Land Unit (CLU), which is "the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer in agricultural land associated with USDA farm programs" (FSA, 2013). In this iteration of the rotation analysis, the CLU boundaries were used as the extent for the rotation analysis instead of the ¼ section boundaries, which provided field-based crop rotation coverage that land management information could be incorporated.

Although the general crop rotation types provide more information than using a single year of the CDL to define agriculture in the WRB, no unified dataset exists to draw information from regarding the other information related to crop rotations – tillage, fertilizer, timing, etc. This is where a balance was struck between relying on the satellite imagery and relying on local knowledge. The satellite imagery is trusted (with confidence percentages hovering around 95%) to spatially identify rotation types better than a local expert, but the local experts were trusted to inform the satellite-identified rotation with the land management information. Local knowledge became essential as county and regional experts were brought together to create regionally-specific information at the quarter section level.

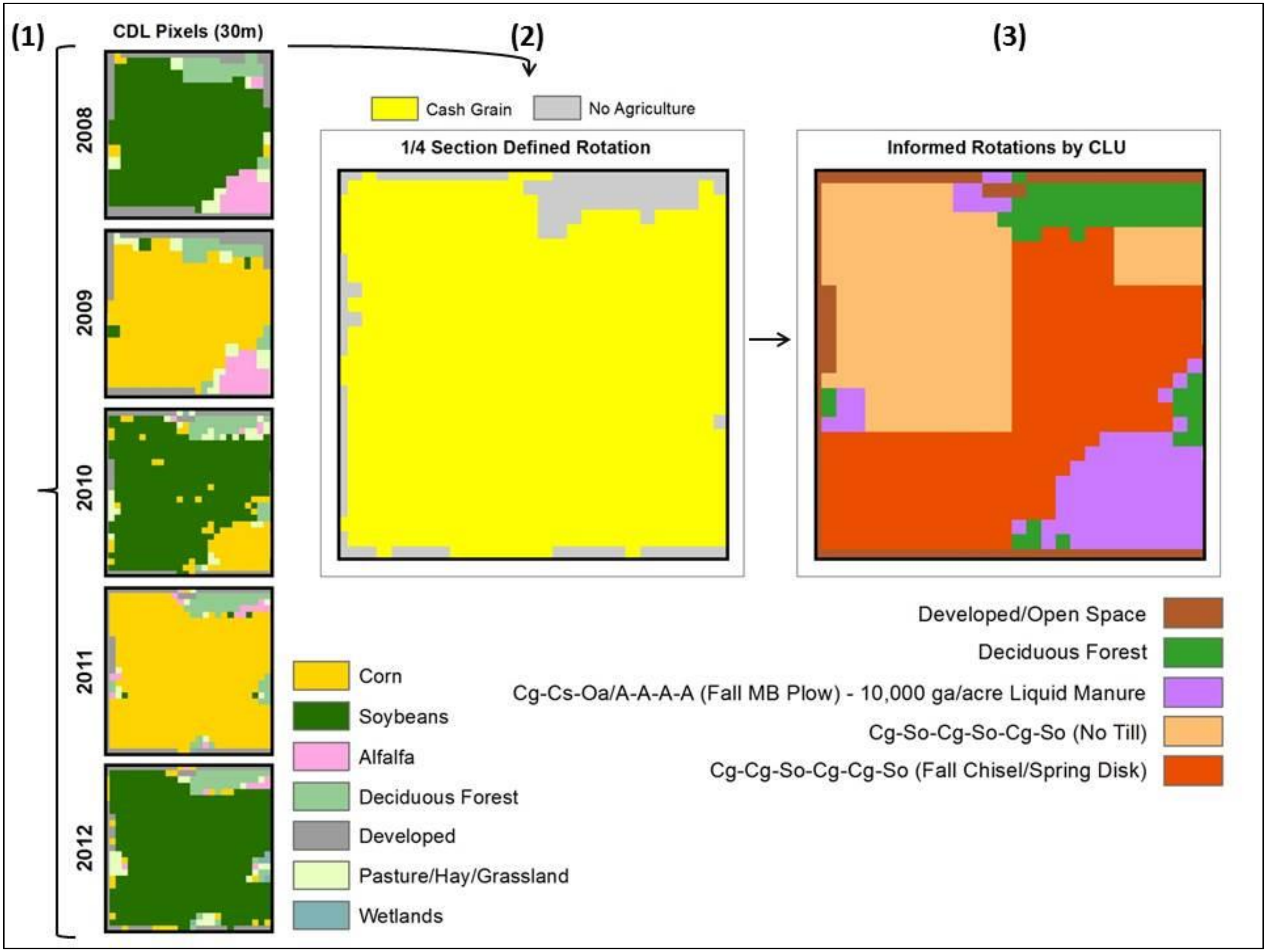


Figure 3: WDNR Approach for Defining Crop Rotations and Land Management for the WRB SWAT model.

3.2.2 Interviews

The second step relies on interviews with local agriculture professionals. The crop rotation dataset described in Section 3.2.1 provides an initial assessment of agriculture, in that it distinguishes between the different crop sequences. However, there were still uncertainties in the development of the initial crop rotation rules. More importantly, the analysis falls short in providing a complete assessment of agricultural management, as it does not ascertain differences in similar rotations based on variability in tillage and nutrient applications. For example, if the geographic variability of dairy operations can be identified, the differences in the rate and timing of manure applications can be acknowledged, leading to better estimates of pollutant contributions. However, these practices differ for all crop rotations types by region based on factors such as soil condition, slope, regional conservation directives, etc. That type of information, at the scale of the modeling effort, could only be found through local knowledge; specifically the information needed to be pre-processed and generalized by those individuals who have on-the-ground experience and the ability to make those generalizations for the modeling effort.

Additionally, there are unique agricultural features that cannot be gleaned from the CDL or the crop sequences, such as drain tiles, irrigation, etc. Again, this type of information is most efficiently documented through conversation with local experts, especially considering the scale and needs of the modeling effort.

The methodology for defining agricultural management through localized knowledge originated from an effort conducted by Adam Freihoefer and Dr. Paul McGinley in 2008. In that study Freihoefer and McGinley assessed the Mead Lake Watershed, a 96 mi^2 watershed in Clark County, Wisconsin, as part of a University of Wisconsin - Stevens Point study of sediment and nutrient export. The project team used a combination of farm surveys, transect surveys, and land evaluations and interviews completed by county staff. The study found that this process was an effective and efficient method for informing the land management dataset. Due to the large scale of the WRB, the WDNR project team decided to use a similar approach. Upon completion of the initial definition of crop sequences using the CDL, meetings were set up with county staff to (1) correct the spatial definition of the sequences and (2) develop underlying management schemes involving the timing of agricultural activities, tillage types, and rate and type of nutrient application (chemical fertilizer or manure). A set of interview questions was created for the county staff along with a brief webinar outlining the project and the goals of the WRB TMDL team (Appendix B).

In July 2013 a webinar describing the WDNR's data collection process was sent to each county land and water conservation office and meetings between individual counties and WDNR were scheduled. Generally, the meetings started with the counties with the smallest percentages of agriculture and progressively organized meetings with counties containing the largest percentages of agriculture in the WRB. The meetings with county land and water conservation staff and their local partners such as county NRCS staff were an iterative process to obtain the detail necessary for the modeling effort. Figure 4 shows a breakdown of the 23 WRB counties in terms of their relative percentages of agricultural land. For time efficiency counties that had a small percentage of agricultural land relative to their total land within the WRB including Forest, Marquette, Shawano, Jackson, Vilas, Price, and Oneida counties were not included as part of the interview process.

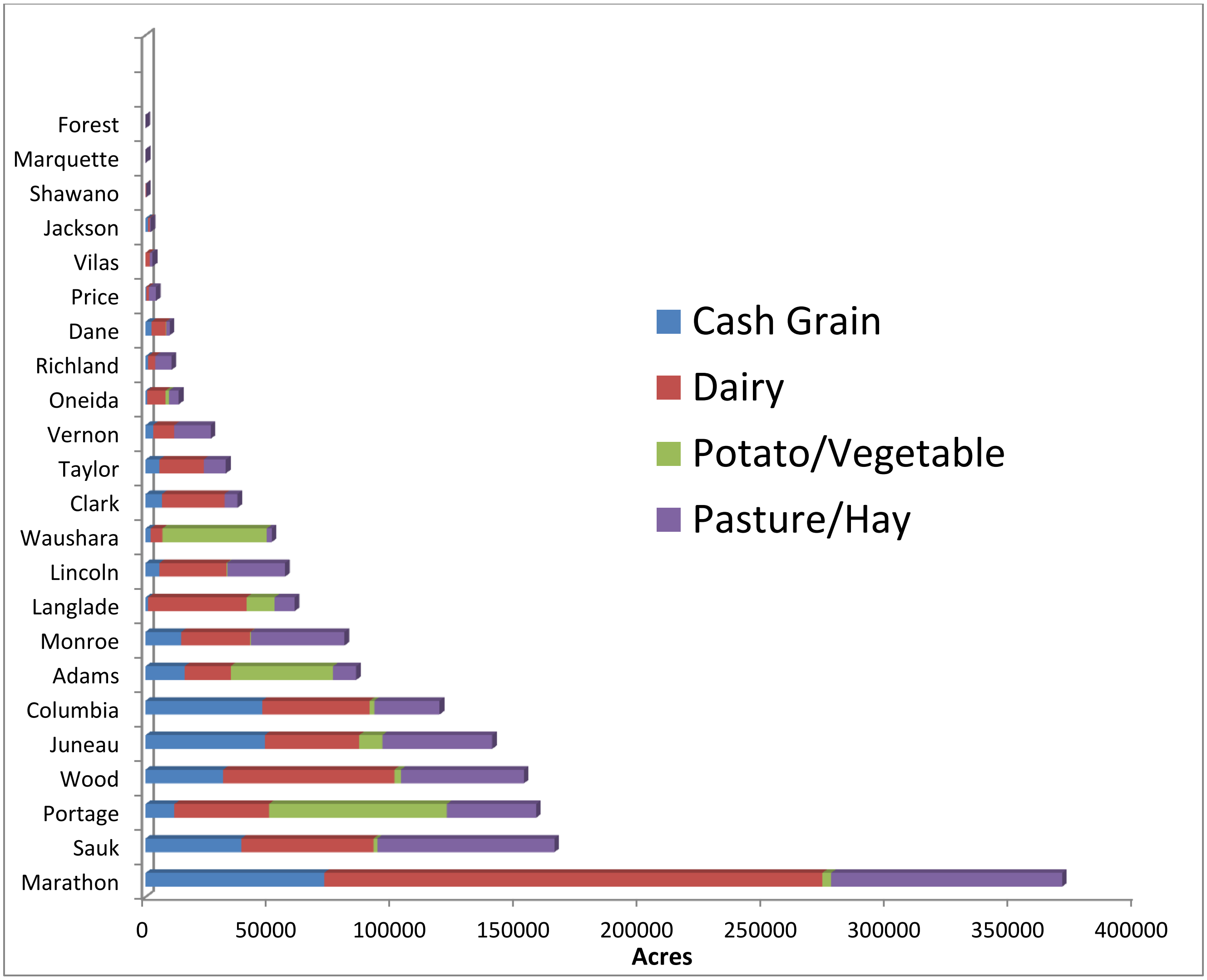


Figure 4: Crop Rotation Acreage Based on WDNR's Cropland Data Layer Sequencing Approach.

The meetings were targeted towards county land and water conservationists and their staff; however, additional expertise from individuals such as University of Wisconsin Extension Agricultural Agents and NRCS staff were welcome and recommended if the county conservationists needed confirmation regarding any component of the agricultural definition. Each meeting lasted between two and four hours and was accompanied by a large map (approximately 3'x4') of the dominant crop rotations per ¼ section (160 acres) that was identified in step 1 using the CDL rules set for 2008-2012. County staff was given a brief description of the meeting objectives including the role of the TMDL towards water quality improvements, the scale of the WRB TMDL model, as well as the level of agricultural land management detail that was required for the model. WDNR provided the counties with several options on how to collect the data including: WDNR staff could work through the map with each county in-person, the counties would complete the map on their own time, or WDNR would provide them the pertinent GIS files so that the counties could update the information in an electronic format. A sample set of the questions asked during the interviews are included in Appendix B.

Additionally, WDNR staff asked for any previously developed relevant datasets. Many counties still collect transect data (or have old transect data) based on the now defunct Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) transect program. The Wisconsin transect survey method is a soil conservation assessment tool that was developed by DATCP and Purdue University (DATCP, 1999). A transect survey is a road-side assessment of crop type, tillage, and residue cover. Transects were intended to be conducted on an annual basis to provide more accountability for soil conservation efforts, as well as be an option for "providing statistically reliable county and state data".

Some counties provided their information on a ¼ section by ¼ section grid; staff would reference plat books, Nutrient Management Plans (NMPs), county GIS data, and other information sources to get the most accurate quarter section level management data. However, some counties opted to take a more generalized approach by providing percentages by region or conditions under which certain management types exist. For example, Marathon County reported that approximately 60% of dairy farmers have a "daily haul" type dairy rotation. However, they estimated that only 40% of the total dairy fields receive daily haul manure.

NMPs were not used to directly inform the definition of rotation as to not bias the model because the NMPs are not readily available throughout the WRB and NMPs tend to favor certain crop rotation types.

For modeling efforts at different scales than the WRB, a different management definition could be chosen. For example, a larger scale model could define land management at the section level (~640 acres), or a smaller scale effort could define land management at the quarter ¼ section scale (~40 acres). The WDNR project team felt that the ¼ section was the most appropriate scale for this model because it both captured the complexity of the WRB agricultural landscape while creating a time efficient rubric for county staff to follow when defining rotations/management.

3.2.3 Data Integration

County staff members served as local experts on agricultural land management identification and refinement of the rotation rules developed in Step 1 of the WDNR approach, but the spatial extent of the crop rotations defined by the USDA CDL were assumed to provide a better spatial definition. The result was two separate datasets created by Steps 1 and 2 requiring the integration of the management information provided by each county and applying it to the WDNR approach developed from the USDA CDL. The following section describes Step 3, the integration of the two data sources.

The final layer integrated the interview-based land management information by ¼ sections into the CDL-based agricultural pixels from the fixed land cover extent. All of the ¼ sections were first converted from vector to raster files and generalized the county-specific rotations into 13 unique crop rotations in addition to "pasture/hay". The counties' land management definitions had to be locally expanded according to the rotation categories from the CDL definition. For example, if the CDL rotation analysis defined a small area of dairy rotation within an area defined by the county staff as a cash grain rotation, the closest dairy rotation management information would be applied to the CDL defined dairy rotation rather than it being overwritten as cash grain.

The ESRI ArcGIS majority filter function was run for the CDL defined rotation categories with the 2008 Common Land Unit (CLU) parcels serving as the area of interest. The majority filter replaces raster cells based on the majority of their contiguous neighboring cells within a defined boundary – the CLU boundaries. The CLU parcels are a USDA Farm Service Agency (FSA) product that is the smallest unit of land that has a permanent, contiguous boundary, a common land cover and land management, a common owner and a common producer in agricultural land associated with USDA farm programs. While the CDL is very accurate it still misidentifies some agriculture pixels, particularly in small plots, so this process eliminated many of the errors in the CDL agricultural definition. Figure 5 demonstrates the evolution of the crop rotation categories from the beginning (1/4 section based, pre-local knowledge) to the final rotations (CLU based, post-local knowledge).

The land management generalizations were then split into distinct spatial layers corresponding to the rotation categories from the CDL rotation definition. All dairy rotations were extracted out and placed into their own spatial layer, all cash grain rotations were extracted out and placed in their own layer, and all potato/vegetable rotations were placed in their own layer. The extents of each layer's rotations were then expanded for the entire WRB so that a unique coverage existed for the entire area for each rotation type (cash grain, dairy, and potato/vegetable). Each of these unique layers was then processed through a conditional evaluation that applied the land management from those layers to their matching crop rotation category from the pixel-based CDL rotation categories. The underlying spatial layers from the county information were then applied to those CDL defined fields. So, for example, anywhere there was a dairy rotation defined by the CDL would get the 6-year rotation information from the nearest dairy rotation from the county informed dairy layer. See Figure 6 for a diagram of this process from start to finish.

Initial Rotations – Pre-Local Knowledge (By 1/4 Section)

	Rotation Type	Acres	Category/Total Acres
Cash Grain	Cash Grain	341,882	Cash Grain – 494,817
	Continuous Corn	152,935	
Dairy	Dairy, 1 Year Corn	22,394	Dairy – 362,973
	Dairy, 2 Years Corn	245,973	
	Dairy, 3 Years Corn	64,207	
	Dairy, Corn/Potato	13,587	
	Dairy, Soybean	16,812	
Potato/Vegetable	Potatoes	10,542	Potato/Vegetable – 141,667
	Potatoes / Corn	17,250	
	Potatoes / Corn / Dry Beans	23,375	
	Potatoes / Corn / Soy	7,149	
	Potatoes / Corn / Vegetables	7,852	
	Potatoes / Dry Beans	8,693	
	Potatoes / Sweet Corn	27,180	
	Potatoes / Sweet Corn / Dry Beans	18,480	
	Potatoes / Sweet Corn / Soy	4,381	
	Potatoes / Sweet Corn / Vegetables	7,480	
	Sweet Corn / Dry Beans	7,367	
	Sweet Corn / Potatoes	1,918	
Pasture/Hay	Pasture/Hay	572,439	Pasture/Hay – 620,342
	Alfalfa	47,903	
Other	Corn, Dry Beans	7,724	Other – 308,150
	Dry Beans	678	
	Insufficient	299,594	
	No Agriculture	154	

Rotations – Post-Local Knowledge (By CLU)

Land Cover	Acres
Cranberries	20,467
Dairy Rotation	487,239
Cash Grain Rotation	257,192
Potato/Vegetable Rotation	172,464
Pasture/Hay	295,325

Rotation Acreage Change

Rotation Type	Change (CLU-1/4 Section Rotations)
Cash Grain	-237,625
Dairy	124,266
Potato/Vegetable	30,797
Pasture/Hay	-325,017

Figure 5: Pre-Local Knowledge Rotations versus Post-Local Knowledge Rotations

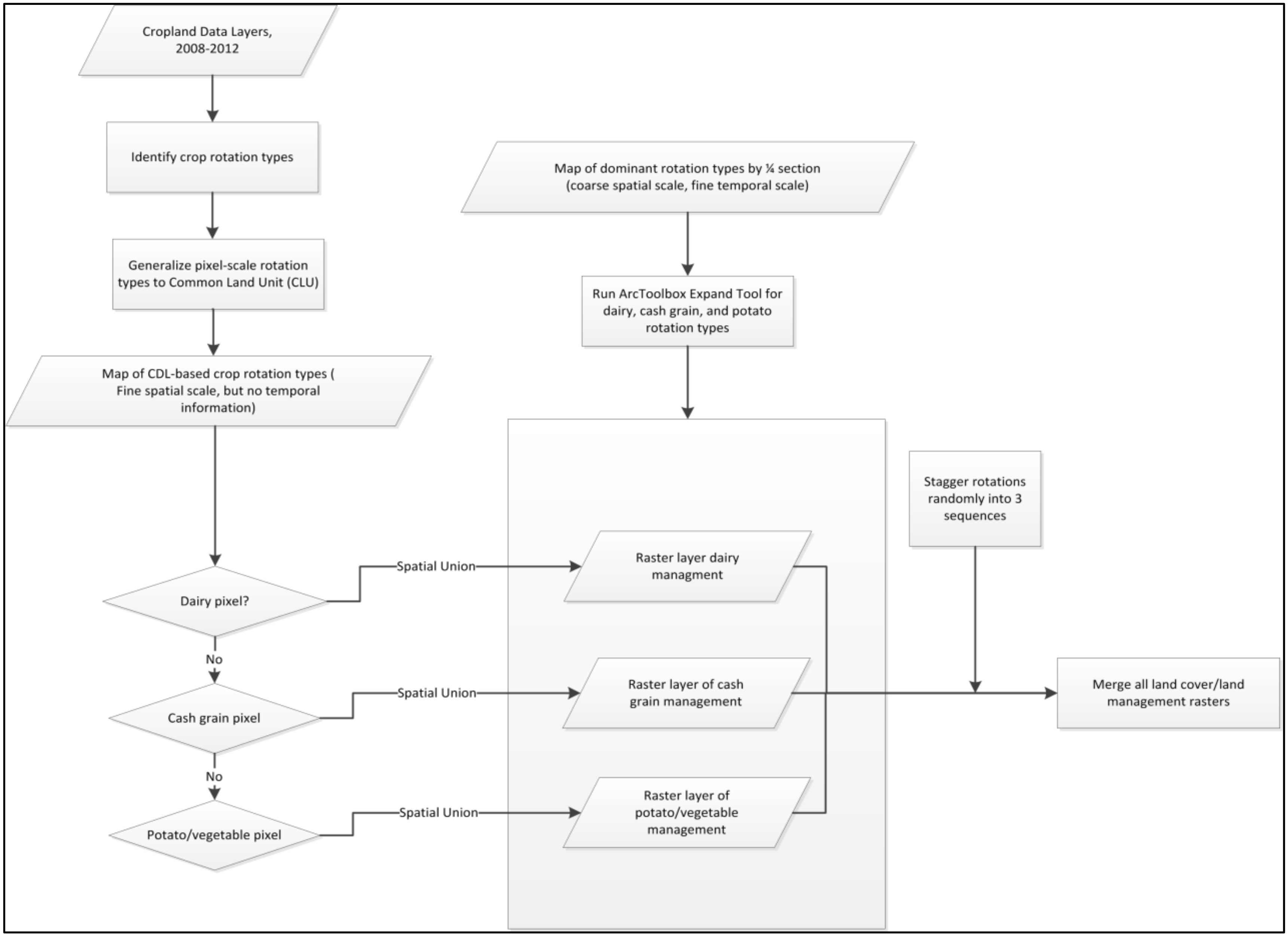


Figure 6: Process of Merging Local Knowledge with CDL Defined Rotations

The next part in data integration process was to synthesize the diverse set of rotations that the county staff had given us. This information was brought into a unified dataset so that duplicates of similar rotations were not created. For example, two different counties may have reported a six year dairy rotation with 2 corn years and 4 years alfalfa, receiving 10,000 gallons/acre/year. In that case one diary rotation would be applied to both counties. Additionally, the number of rotations needed to be reduced as much as possible for computational suitability in the SWAT model, while also keeping the data integrity of the county reported information.

Initial similarities and differences were drawn between the reported rotations internally, using best professional judgment. However, a third party review was conducted to verify the conclusions that were made regarding crop rotations. A panel of other WDNR staff, faculty from the Unversity of Wisconsin, and private agronomists, manure haulers, and crop consultants were invited to a three hour discussion of the agricultural management data that had been created. The agricultural management process was well received by the group and only minor adjustments were made to a few of the rotations. For example, the starter fertilizer applications were changed from 200lbs/acre/year to 150lbs/acre/year. Additionally, the group was able to establish a consensus for some of the validation methods that were uncertain. For instance, an outcome of this meeting was that most dairy operations across the basin keep 50% adult cows and 50% heifers and calves, which was extremely important for the manure totals comparison by county.

Three variations of each rotation were created to acknowledge that any farms growing the same rotation are likely not in the same year of the rotation. If the variations were not created it would result in the same crop of a specific rotation (e.g. corn) being applied to all areas where that rotation was present. These three variations were offset by two years. So, for example, a Cg-Cg-A-A-A-A dairy rotation would be split into the following three rotation sequences: Cg-Cg-A-A-A-A, A-A-A-A-Cg-Cg, and A-A-Cg-Cg-A-A.

The generalized rotations were entered into a database where each activity was stored for the 6 year period. In total 15 rotations (11 dairy, 3 cash grain, and 1 potato/vegetable) were created for the WRB, based on the data from the CDL, information from county and regional staff, NASS census data, and information from our meeting with various crop consultants. Each of the 15 rotations had three variations, resulting in 45 rotations that were incorporated into the SWAT model.

3.3 Validation

The fourth and final step of the WDNR approach involved using validation datasets to ensure that the final crop rotation dataset produced in Step 3 was accurate. These validation datasets included DATCP cattle inventory records, NASS crop acreage reports by county, DATCP dairy producer points, and transect surveys.

3.3.1 Transects

The Wisconsin transect survey method is a soil conservation assessment tool that was developed by DATCP and Purdue University (Wisconsin County Transect Survey 1999). A transect survey is a road-side assessment of crop type, tillage, and residue cover. Transects were intended to be conducted on an annual basis to provide more accountability for soil conservation efforts, as well as be an option for “providing statistically reliable county and state data”. Five of the counties in the WRB had relevant transect data; Sauk County provided data from 2008-2013, Vernon County provided data from 2009-2013, Marathon County provided data from 2006-2013, Juneau County provided data from 2005-2010, and Wood County provided data from 2005-2012. In all 2,617 transect points were surveyed within the WRB. However, not every survey point had complete data for all years.

The crop types from the transect data were concatenated for each point using the same rules set as the CDL rotation identification. This provided a qualitative baseline assessment of the accuracy of the rotation types defined by the CDL. However, the two differed spatially since the transect points are not generalized for dominance within their respective ¼ sections, but rather, are specific to a field. As a result, a general trend comparison between the countywide rotation distribution from the CDL rotation to the countywide rotation distribution from the transect data was made (Figure 7). Generally, we saw the same distribution of crop rotations, which helped validate the WDNR Approach for crop rotation identification (Table 1). Unfortunately, the comparison of the WDNR Approach to the transect data is limited by the transect data making the comparisons in Table 1 more difficult, particularly in regards to potato/vegetable rotations.

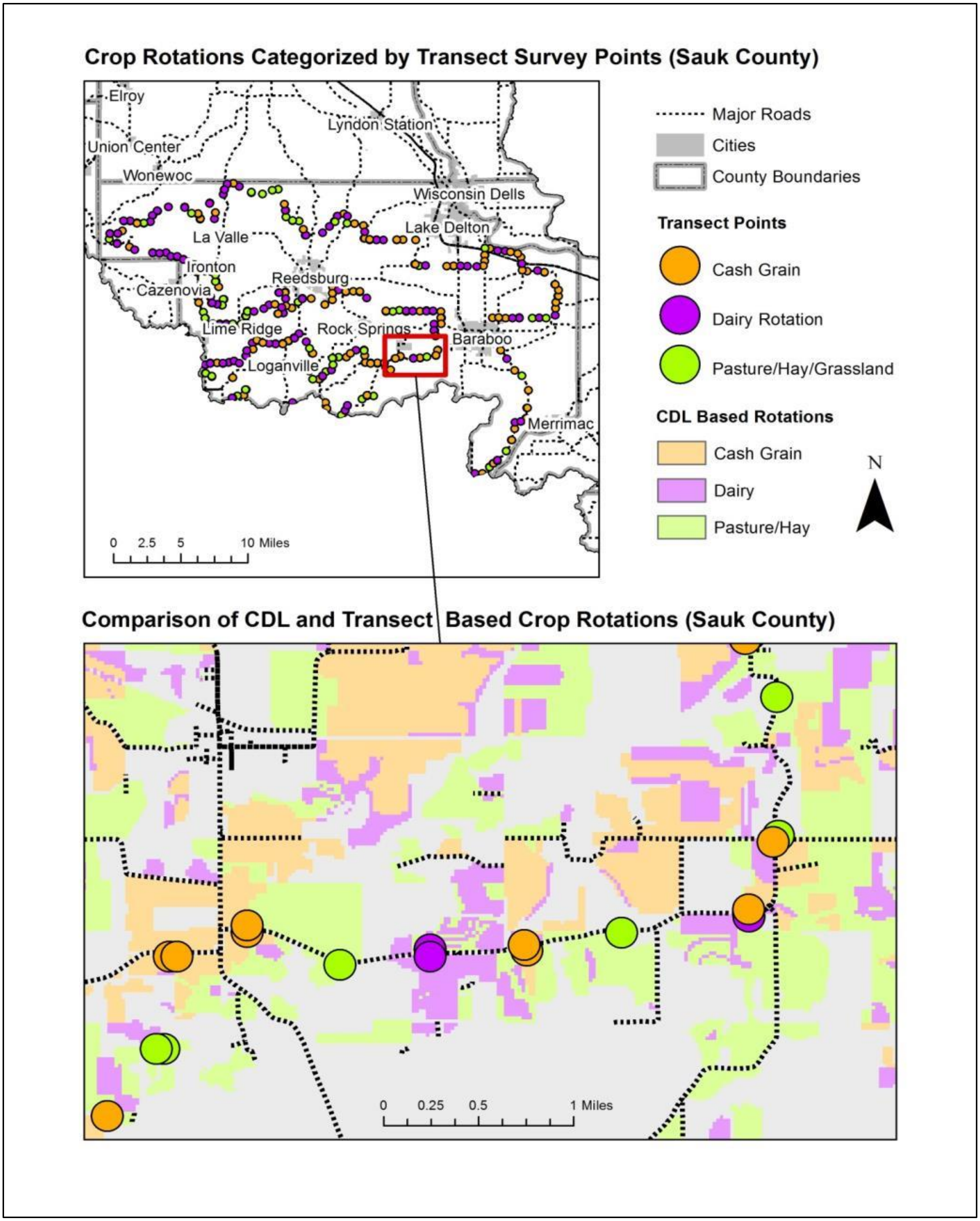


Figure 5: Comparison of Transect Based Crop Rotations to CDL Based Crop Rotations in Sauk County.

Table 1: Distribution of Transect Point Rotations (Juneau, Marathon, Sauk, Wood, and Vernon Counties)

Rotation Type	Transect Count	Transect %	WDNR Approach Acreage	WDNR Approach %
Cash Grain	608	23	309,228	20
Dairy	946	36	633,315	40
Pasture/Hay	414	16	447,013	28
Potato/Vegetable	68	3	187,924	12
Insufficient	581	22	-	-
Total	2,617	100	1,577,481	100

More importantly the transect surveys were used for both validation of the information county staff had given us and as a guideline for areas where gaps existed in the data. For example, most of the counties had reported two years of corn (either for grain or silage) in a six year dairy rotation. However, there were a few exceptions where three or four years of corn in a six year dairy rotation was reported as the most common. To assess the validity of this the number of corn years observed in a 6 year period from transect data at dairy field points was examined. Figure 8 shows the distribution of corn years in dairy rotations from Marathon, Sauk, Juneau, and Wood Counties. This transect information demonstrates that 6 year dairy rotations do in fact have approximately two years of corn on average.

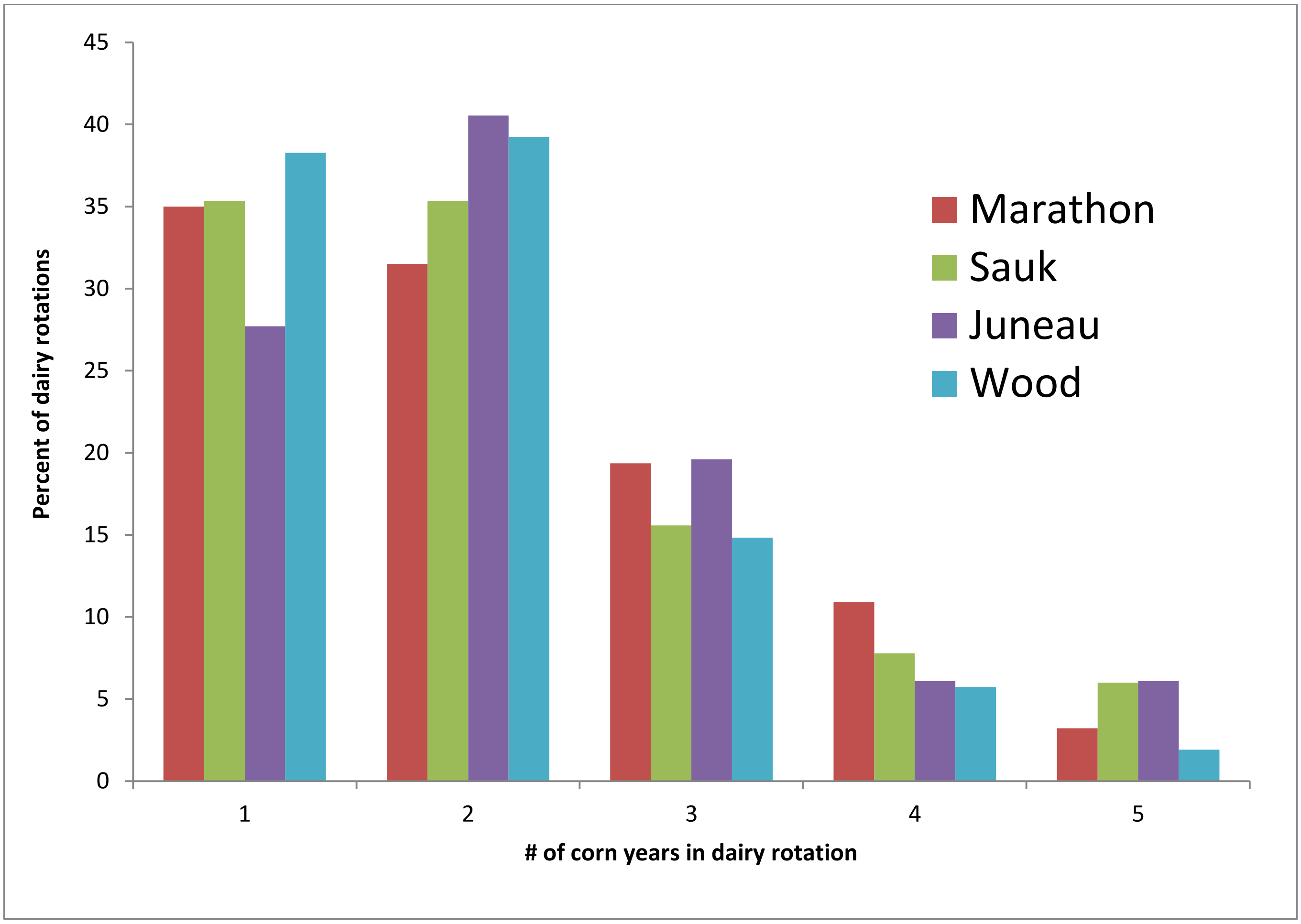


Figure 6: Corn Years in 6-Year Dairy Rotations Identified from Transect Surveys.

3.3.2 Crop Acreage

The process of identifying crop rotations for the WRB TMDL was to define the agricultural extent from the static landcover, create generalized rotations based solely on an annual crop sequence from the CDL, and then attach county/regional information to those CDL crop sequence rotations. A simple check to see if the crop acreage was still accurate after this generalization process was to compare a given crop's extent from the CDL with the given crop's extent post-CDL rotation generalizations. Corn is the crop with the highest user and producer accuracies that the CDL identifies, is the most predominant crop in harvested acreage, and is included in the widest variety of rotation types. For these reasons, it was the best crop to use for comparison with the generalized rotations that were developed. As shown in Figure 9 the average annual corn acreage from the CDL is very similar to average annual corn acreage in the WDNR approach.

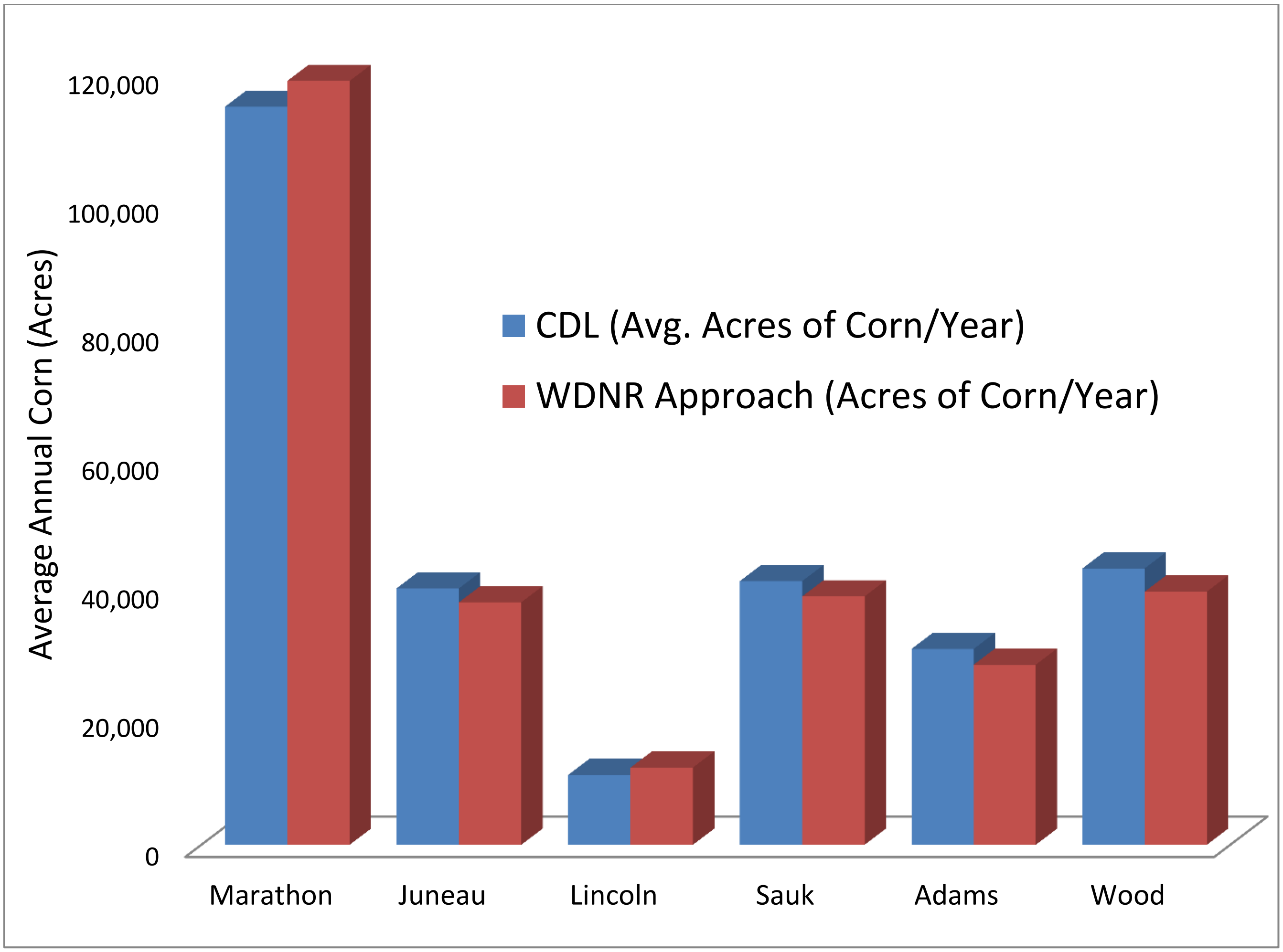


Figure 9: Average Corn Acreage from the Cropland Data Layer (2008-2013) Versus Corn Acreage using the WDNR Approach.

3.3.3 Dairy Producer Locations

The DATCP licensed dairy producer locations were used to develop a density map of dairy farmers. This density map is based on location of licensed dairy farm facilities, not the location and subsequent density of dairy farm fields. However, when the producer location densities were compared to the density of dairy rotation fields from the CDL analysis there are very similar trends. The initial concern was that the dairy rotation density would just follow the general density of agricultural production. However, it can be seen in Figure 10 that the non-dairy rotations defined by the CDL follow a distinctly different pattern. This validation helped to corroborate the other analyses, as it provided more certainty in the WDNR approach's ability to identify dairy fields.

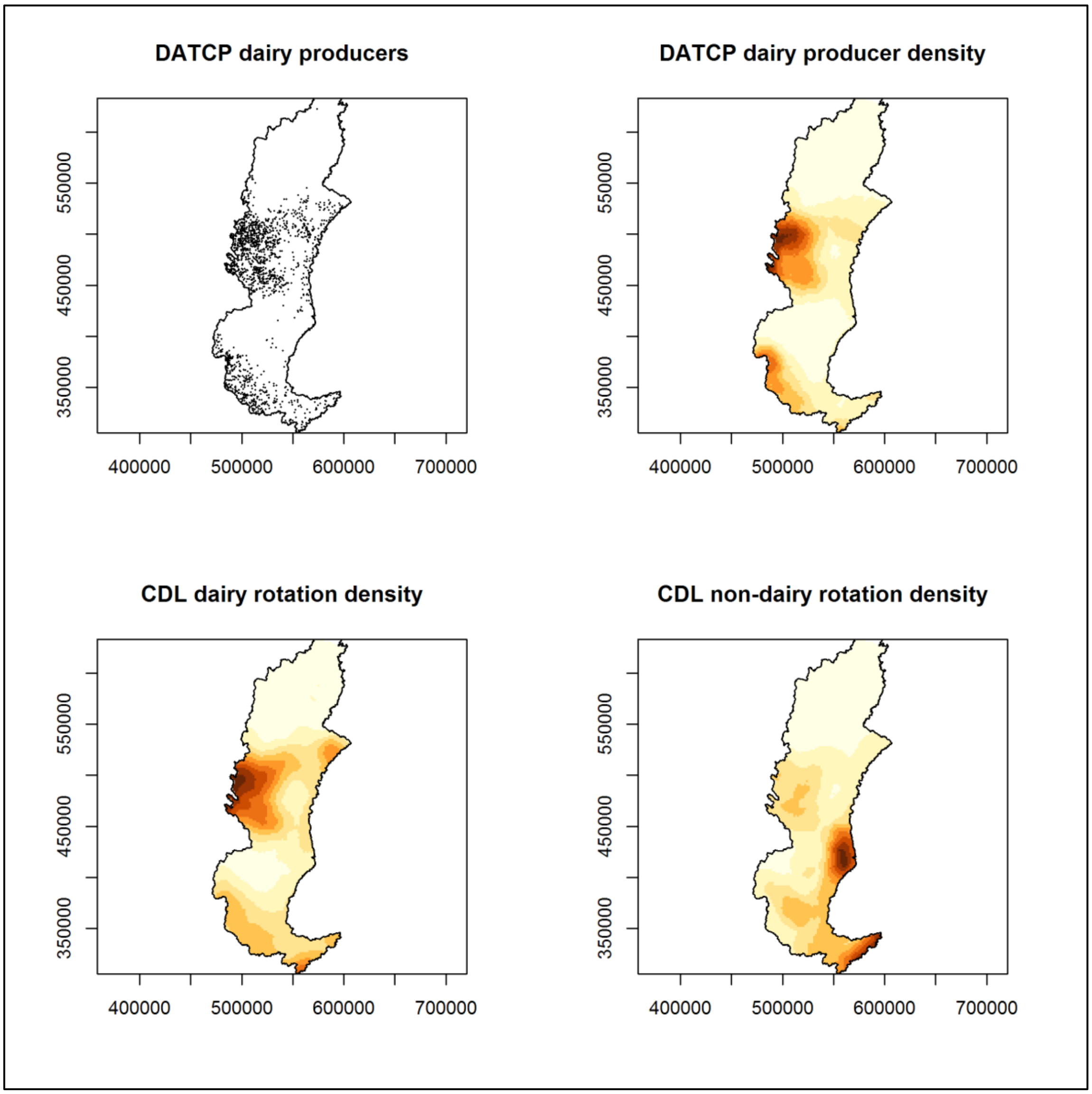
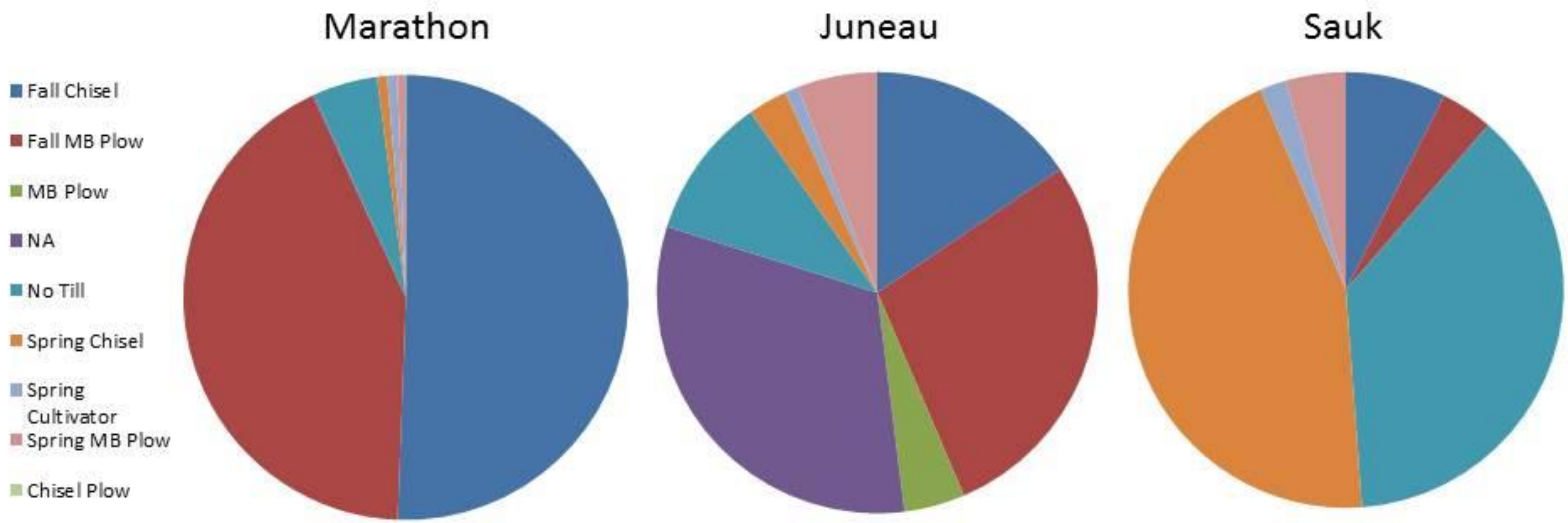


Figure 10: Dairy Producer Location Density Compared with CDL Defined Rotations within WRB

3.3.4 Tillage Validation

The transect data also provided us with tillage information by crop type. The tillage information from the transects was compared with the information that the county/regional staff provided. The tillage information was very dense and there was not consistent naming of the tillage types by county. However, the general tillage types and timing were interpreted by looking at the predominant tillage by crop type. Figure 11 shows what the general tillage patterns look like for three of the major counties: Marathon, Juneau, and Sauk. This data corroborated what we heard from county staff, which was that fall tillage is predominant in the north central WRB and that spring tillage is predominant in the southern WRB. Note that all of the transect points were used in Figure 11, so the tillage reported is for all crop types under all rotations for each county.



County	# Transects	Fall %	Spring %	No Till %
Marathon	2207	95.8	2.1	2.1
Juneau	6314	80.8	18.0	1.1
Sauk	1544	11.3	51.2	37.5

Figure 11: Transect Tillage Information for Marathon, Juneau, and Sauk Counties

3.3.5 Manure Validation

Similar to past SWAT applications, cattle inventories were used to validate the amount of manure application reported by the counties, as well as the extent of our dairy rotation identification (Baumgart 2005, Freihoefer and McGinley 2008, Timm and McGinley 2011).

This was done by calculating an average manure output per cow per year, multiplying that value by the total number of cows per county, and then comparing that value with the total average amount of manure applied per year to dairy fields. Of course, not all cow manure is captured and applied to dairy fields. There are other management schemes such as managed grazed lands, seasonally pastured animals, etc. that must be accounted for. Additionally, there are circumstances where manure is applied to non-dairy rotations, sold to other non-dairy farmers, used for non-fertilizer needs, etc. These are difficult situations to account for, thus the estimates only needed to align closely with the cattle inventory values.

SWAT uses dry weight values for manure application, so reported values of liquid and solid manure were converted to dry weight values in kg/ha. The conversion process required the determination of the dry weight percentages of dry manure and liquid manure. Based on previous research 6% dry weight for liquid manure and 24% dry weight for solid manure were used (Jokela and Peters 2009, Laboski and Peters 2012, NRCS 2006). For liquid manure conversions, it was also assumed that there are 8.34 pounds per every gallon of manure based on the DATCP dairy manure estimation calculator.

As mentioned previously, it was learned that the general distribution of cattle sizes on a dairy farm is approximately 50% calves and heifers (approximately 150-750lbs.) and 50% lactating and dry adult cows (750-1400lbs.). According to the DATCP dairy manure output values from the manure estimation calculator and the animal size distribution estimates, the average manure output per dairy cow is 16 tons/acre/year (DATCP, 2000).

Figure 12 shows the manure comparisons for 6 of the major WRB counties. See Appendix E for a table of manure comparison calculations for these counties.

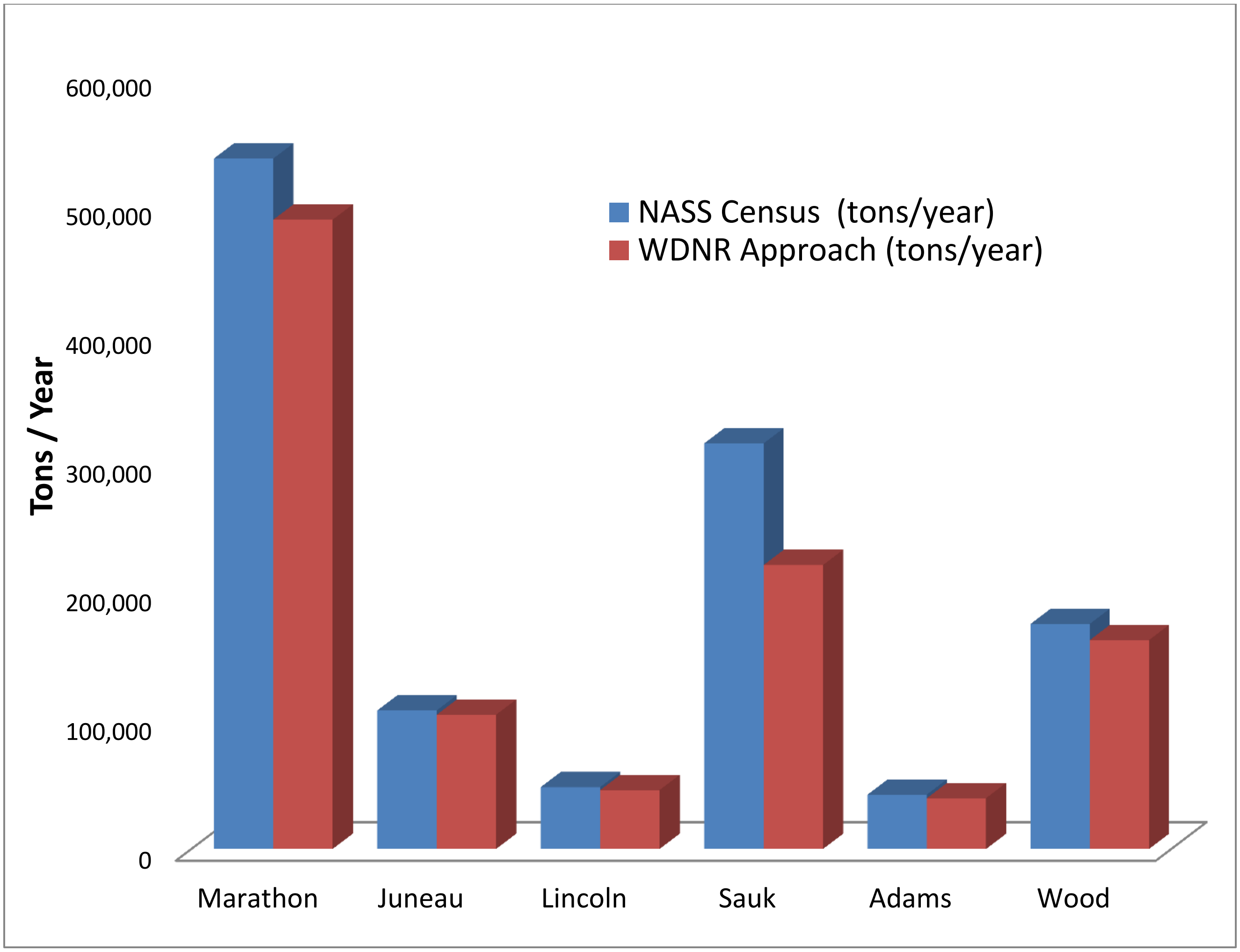


Figure 7: DATCP Cattle Inventory Manure Amounts Versus Manure Applied Using WDNR Approach.

3.4 Other Agricultural System Components

Certain aspects of agricultural land use were difficult to ascertain. Therefore, additional modeling techniques must be used to represent certain land use practices.

3.4.1 Cranberries

Cranberries play a role in the hydrology of localized areas within the WRB, such as areas near Tomah and Wisconsin Rapids. However, there is little Wisconsin-based cranberry research regarding phosphorus output from cranberry bogs. Previous literature suggests a concentration of phosphorus in water exiting cranberry farms is generally 0.04 mg/L (Roper 2005), but often cranberry bogs drain water through pulse releases – which potentially have much higher phosphorus concentrations (DeMoranville and Howes 2005). These "closed bogs" release water most often after flooding for harvest in the fall, protection from freezing in the winter, and protection from frost in the spring if there is a prolonged cold streak. "Flow through" bogs are less common in Wisconsin, but are cranberry operations that are characterized by streams that actually enter and flow through the bog complex.

3.4.2 W-Structures

Interviews with Marathon County conservation staff indicated that much of Marathon County's agricultural landscape west of the Wisconsin River is drained by "W-Structures" or sometimes called "W-ditches". According to the LWCD, these structures were created in the early part of the 20th century to improve drainage on the tough, clayey soils of Marathon County. As their name implies, when looking from a side view, the structures form the shape of a W; two ditches are created with a peak in the middle. From a plan-view they look like parallel channels and are easily recognizable using aerial imagery products like Google Earth. Unfortunately, there is currently no methodology for spatially identifying these structures; it is only known that they are ubiquitous throughout the agricultural land in Marathon County west of the Wisconsin River. So, while they cannot be identified individually, their role will be mimicked in the surface water hydrology of the model to account for their impact to the hydrograph.

3.4.3 Tile Drainage

Tile drainage is prevalent throughout the WRB. The topic was always integrated into the county interviews, but over the course of the project it was found that because the full extent of tile drainage is not known for the WRB, it may bias the model by using county-specific tile drainage data in one county while not using it in another county. To remedy that data gap a combination of slope, soil type, and agricultural land class will be used to determine tile drained fields since tile drainage is a function of limitations to crop growth from over saturation.

3.4.4 Irrigation

The WDNR high capacity well locations were used to inform irrigation in the WRB. Irrigation is most common in the Central Sands region, particularly on potato/vegetable rotations. For this reason, irrigation will only be applied to potato/vegetable rotations in the Central Sands region.

3.5 Limitations

A few questions remain regarding land management and its impact on the WRB landscape. The following issues will be dealt with in the coming months as the modeling effort continues to develop. The WRB TMDL project team will continue to be open to comments/concerns regarding these issues as decisions are made about their incorporation into the model.

3.5.1 Pasture vs. Hay vs. Grassland Definition

A reoccurring question with respect to land cover definition throughout the upper Midwest is how to distinguish pastured land from hay ground from nonagricultural grassland. What was seen as the CDL's biggest limitation is its inability to distinguish between these land cover types as they are different types of land management of similar ground cover, so using satellites to identify them with static imagery is a challenge. The managed grazed lands locations from Golden Sands RC&D and Marathon County accounted for managed grazed lands in many of the major counties, but there are certainly other lands that are continuously pastured or continuously harvested for hay that we did not define (Paine and Gildersleeve 2011). Originally, the managed grazed lands were going to be incorporated into the landcover layer, but were ultimately not included due to biasing issues as only a few counties were very well represented. The one omission that was made from the pasture definition was woodland pastured grazing. The spatial identity of woodland pasture grazing areas was not inclusive and is another example of data that could be obtained during watershed implementation at a small scale (less than 30 mi^2).

3.5.2 Changing Land Management

Land management schemes during the model simulation period (2002-2013) were not static. One major change was the rapid increase in the price of corn around the middle of the simulation period. This caused many farmers to grow more corn grain acreage than was typical when corn was lower priced. This meant that many CRP contracts were not renewed, corn grain replace many corn silage fields, and dairy farmers were planting more years of corn in a corn/hay rotations than in previous years. This made it difficult to create two generalized 6-year rotations for the 12 year model period, as it's challenging to generalize something that's evolving. Given this dilemma, every attempt was made to create generalized rotations with local experts that best represented the predominant land management patterns for the model period by being upfront about the issue.

4.0 Final Product

The final product is a 30 m^2 raster-based data layer with land cover and land management defined for the entire WRB. The final dataset, which can be viewed through GIS and can be incorporated into the SWAT model, will serve as the land cover parameter layer for the WRB TMDL modeling effort. The data layer can also serve as a template for further modeling efforts or other studies. The crop rotation categorization analysis was completed for the entire state of Wisconsin so that the layer could be populated with regional land management information for other applications.

The final crop rotation datasets, as well as the datasets used to create them, are publicly available from the WDNR. If interested please inquire with the Wisconsin River TMDL Project Manager at dnrwisconsinrivertmdl@wisconsin.gov.

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APPENDICES

Appendix A

WDNR Approach for Grouping CDL Land Cover Classes and Final Rotation Rules

2012 Wisconsin
Land Cover Categories (by decreasing acreage)

AGRICULTURE

- Corn
- Pasture/Grass
- Alfalfa
- Soybeans
- Other Hay/Non Alfalfa
- Winter Wheat
- Oats
- Potatoes
- Dry Beans
- Sweet Corn
- Peas
- Clover/Wildflowers
- Fallow/Idle Cropland
- Barley
- Rye
- Spring Wheat
- Cabbage
- Carrots
- Herbs
- Christmas Trees
- Cranberries
- Canola
- Triticale
- Cucumbers
- Sod/Grass Seed
- Sugarbeets
- Sunflower
- Sorghum
- Dbl Crop WinWht/Soybeans
- Cherries
- Millet
- Onions
- Other Crops
- Peppers
- Dbl Crop WinWht/Sorghum
- Dbl Crop WinWht/Corn
- Buckwheat
- Blueberries
- Aquaculture
- Greens
- Tobacco
- Apples
- Pumpkins
- Squash
- Vetch
- Strawberries
- Asparagus
- Flaxseed
- Grapes
- Pop or Orn Corn
- Radishes
- Dbl Crop Soybeans/Oats
- Misc Vegs & Fruits
- Dbl Crop Oats/Corn
- Dbl Crop Corn/Soybeans
- Other Tree Crops
- Pears

NON-AGRICULTURE

- Forest
- Wetlands
- Developed
- Water
- Shrubland
- Barren

WDNR Approach Land Cover Group	Cropland Data Layer 2012 Land Cover Type
Corn	Corn
Alfalfa	Sorghum, Barley, Durum Wheat, Spring Wheat, Winter Wheat, Other Small Grains, Rye, Oats, Millet, Speltz, Alfalfa, Buckwheat, Clover/Wildflowers, Triticale
Pasture/Hay	Other Hay/Non-Alfalfa, Pasture/Grass, Pasture/Hay
Soybeans	Soybeans
Potatoes	Potatoes
Vegetables	Onions, Cucumbers, Peas, Carrots, Peppers, Sweet Corn
Non-Agriculture	All other Land Cover Categories

Rotation Type	Rule Per $30m^2$ Pixel (2008-2012)
Non-agricultural	If pixel is non-agricultural for all 5 years
Cash Grain	Corn ≥ 1 year, Soybeans ≥ 1 year, Pasture/Hay and Alfalfa ≤ 1 year, & Potatoes + Vegetables = 0 years
Pasture/Hay	Pasture/Hay + Alfalfa ≥ 2 years, & Corn + Soybeans + Potatoes + Vegetables = 0 years
Dairy Rotation	Corn ≥ 1 year, Pasture/Hay + Alfalfa ≥ 1 year, & Potatoes + Vegetables = 0 years
Potato/Vegetable	Potatoes ≥ 1, & Corn + Soybeans + Vegetables + Pasture/Hay + Alfalfa ≥ 2 years

Appendix B

Example Interview Questions

1) What are the approximate planting dates and harvest dates for each crop type identified on the map?
2) Agricultural areas were identified as "insufficient" if we did not have enough data to define a certain crop rotation. Identifying these areas, however, is very important for our modeling efforts. Are there "insufficient" areas that you can tell us about? Do you know the general crop rotations?
3) Can we make any inferences about certain crop rotation schemes? (An example might be that any continuous corn crop rotation means that they certainly don't do no-till, etc.)
4) One of our greatest struggles has been distinguishing between satellite imagery results for areas identified as land cover types such as pasture, hay, grassland, etc. Are you able to generally identify which areas are grazed, which are harvested, and which are left unutilized? Can you distinguish between light pasture (low animal density) and heavy pasture (high animal density)?
5) Are there crop rotations that you know of in your county that aren't represented on the map?
6) Are there areas where farmers are growing multiple crops per season? Additionally, are cover crops a common practice in your county? If so, can cover crops be correlated with a certain crop type or crop rotation?
7) The satellite imagery can only distinguish between corn and sweet corn. It can't identify seed corn vs. feed corn vs. corn for ethanol or grain products. More importantly, it can't provide information about what corn is silage and what isn't. Are there any general assumptions that can be made about grain rotations and their likelihood of being used for silage?
8) In (insert county name), are there general relationships between the crop rotation type and the tillage practices? Or, are there relationships between the general geographic location and the tillage practices (in example, the southwest portion of the county may cultivate more often than the northeast)?
9) Can tillage practices be correlated with things other than rotation? For instance, are there soil type limitations that create tillage differences across the county?
10) What are the approximate tillage dates for the different crop rotations?
11) What are the predominant tillage patterns, in terms of timing and type of tillage?
12) Are tillage practices generally predictable, or do they vary year-to-year (based on market pressures, environmental conditions, etc.)?
13) Is there a relationship between crop rotation type and nutrient application?
14) For each rotation, can you provide an estimate as to how much is applied, how often it is applied, and what type is applied?
15) What rotations receive chemical fertilizer?
16) What are the most common N:P:K ratios in your county for chemical fertilizers?
17) Are there any "hotspots" that require further investigation?
18) Are there any areas pertinent to nutrient runoff that you can identify? These might be landscape factors such as areas of major erosion, water diversion systems, soil conservation efforts, etc.
19) Are there areas where you can identify tile drainage?
20) Is tile drainage field specific or is it a function of slope, soil type, or some other land characteristic?
21) Are there any other concerns you think should be considered when assessing phosphorus and sediment contributions from your county as part of the Wisconsin River Basin TMDL?

Appendix C

Generalized Rotations by Name and Code

300 - Cg-Cs-O/A-A-A-A (LQ) Spring Chisel -10,000 ga/acre/yr

Year	Month	Day	Operation	Type	Amount	Unit
1	4	29	Manure	Dry Weight	5,582	kg/ha
1	5	1	Tillage	Chisel Plow		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
2	4	29	Manure	Dry Weight	5,582	kg/ha
2	5	1	Tillage	Chisel Plow		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
3	4	14	Manure	Dry Weight	1,675	kg/ha
3	4	17	Tillage	Chisel Plow		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

301 - Cg-Cs-O/A-A-A-A (DH) Spring Chisel - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Manure	3362.5	kg/ha
1	2	28	Manure	Dry Manure	3362.5	kg/ha
1	3	31	Manure	Dry Manure	3362.5	kg/ha
1	4	29	Manure	Dry Manure	3362.5	kg/ha
1	5	1	Tillage	Chisel Plow		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168.0	kg/ha
1	11	1	Harvest	Corn Grain		
2	1	31	Manure	Dry Manure	3362.5	kg/ha
2	2	28	Manure	Dry Manure	3362.5	kg/ha
2	3	31	Manure	Dry Manure	3362.5	kg/ha
2	4	29	Manure	Dry Manure	3362.5	kg/ha
2	5	1	Tillage	Chisel Plow		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168.0	kg/ha
2	9	15	Harvest	Corn Silage		
3	1	31	Manure	Dry Manure	1120.8	kg/ha
3	2	28	Manure	Dry Manure	1120.8	kg/ha
3	3	31	Manure	Dry Manure	1120.8	kg/ha
3	4	14	Manure	Dry Manure	1120.8	kg/ha
3	4	17	Tillage	Chisel Plow		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

302 - Cg-O/A-A-A-A-A (DH) Spring Chisel - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Weight	3362.5	kg/ha
1	2	28	Manure	Dry Weight	3362.5	kg/ha
1	3	31	Manure	Dry Weight	3362.5	kg/ha
1	4	29	Manure	Dry Weight	3362.5	kg/ha
1	5	1	Tillage	Chisel Plow		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
2	1	31	Manure	Dry Weight	1,121	kg/ha
2	2	28	Manure	Dry Weight	1,121	kg/ha
2	3	31	Manure	Dry Weight	1,121	kg/ha
2	4	14	Manure	Dry Weight	1,121	kg/ha
2	4	17	Tillage	Chisel Plow		
2	4	25	Plant	Alfalfa		
2	8	10	Harvest	Alfalfa		
3	6	1	Harvest	Alfalfa		
3	7	15	Harvest	Alfalfa		
3	8	30	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

303 - Cg-Cs-O/A-A-A-A (LQ) Fall Chisel -10,000 ga/acre/yr

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	12	Manure	Liquid	5,582	kg/ha
1	11	15	Tillage	Chisel Plow		
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	15	Manure	Liquid	5,582	kg/ha
2	10	18	Tillage	Chisel Plow		
3	4	14	Manure	Liquid	1675	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

304 - Cg-Cs-O/A-A-A-A (DH) Fall Chisel - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Weight	3362.5	kg/ha
1	2	28	Manure	Dry Weight	3362.5	kg/ha
1	3	31	Manure	Dry Weight	3362.5	kg/ha
1	4	29	Manure	Dry Weight	3362.5	kg/ha
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168.0	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	15	Tillage	Chisel Plow		
2	1	31	Manure	Dry Weight	3362.5	kg/ha
2	2	28	Manure	Dry Weight	3362.5	kg/ha
2	3	31	Manure	Dry Weight	3362.5	kg/ha
2	4	29	Manure	Dry Weight	3362.5	kg/ha
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	150.0	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	1	Tillage	Chisel Plow		
3	1	31	Manure	Dry Weight	1120.8	kg/ha
3	2	28	Manure	Dry Weight	1120.8	kg/ha
3	3	31	Manure	Dry Weight	1120.8	kg/ha
3	4	14	Manure	Dry Weight	1120.8	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

305- Cs-Cs-O/A-A-A-A (LQ) Fall Chisel -10,000 ga/acre/yr

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Silage		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	9	15	Harvest	Corn Silage		
1	10	15	Manure	Liquid	5,582	kg/ha
1	10	18	Tillage	Chisel Plow		
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	15	Manure	Liquid	5582	kg/ha
2	10	18	Tillage	Chisel Plow		
3	4	14	Manure	Liquid	1,675	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

306 - Cs-Cs-O/A-A-A-A (DH) Fall Chisel - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Weight	3362.5	kg/ha
1	2	28	Manure	Dry Weight	3362.5	kg/ha
1	3	31	Manure	Dry Weight	3362.5	kg/ha
1	4	29	Manure	Dry Weight	3362.5	kg/ha
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Silage		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	9	15	Harvest	Corn Silage		
1	10	1	Tillage	Chisel Plow		
2	1	31	Manure	Dry Weight	3362.5	kg/ha
2	2	28	Manure	Dry Weight	3362.5	kg/ha
2	3	31	Manure	Dry Weight	3362.5	kg/ha
2	4	29	Manure	Dry Weight	3362.5	kg/ha
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	1	Tillage	Chisel Plow		
3	1	31	Manure	Dry Manure	1120.8	kg/ha
3	2	28	Manure	Dry Manure	1120.8	kg/ha
3	3	31	Manure	Dry Manure	1120.8	kg/ha
3	4	14	Manure	Dry Manure	1120.8	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	Chisel Plow		

307 - Cs-Cs-O/A-A-A-A (LQ) Fall MB Plow -10,000 ga/acre/yr

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Silage		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	9	15	Harvest	Corn Silage		
1	10	15	Manure	Liquid	5,582	kg/ha
1	10	18	Tillage	MB Plow		
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	15	Manure	Liquid	5,582	kg/ha
2	10	18	Tillage	MB Plow		
3	4	14	Manure	Liquid	1,675	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	MB Plow		

308 - Cs-Cs-O/A-A-A-A (DH) Fall MB Plow - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Weight	3362.5	kg/ha
1	2	28	Manure	Dry Weight	3,363	kg/ha
1	3	31	Manure	Dry Weight	3,363	kg/ha
1	4	29	Manure	Dry Weight	3,363	kg/ha
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Silage		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	9	15	Harvest	Corn Silage		
1	10	1	Tillage	MB Plow		
2	1	31	Manure	Dry Weight	3,363	kg/ha
2	2	28	Manure	Dry Weight	3362.5	kg/ha
2	3	31	Manure	Dry Weight	3362.5	kg/ha
2	4	29	Manure	Dry Weight	3362.5	kg/ha
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	150	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	1	Tillage	MB Plow		
3	1	31	Manure	Dry Manure	1120.8	kg/ha
3	2	28	Manure	Dry Manure	1120.8	kg/ha
3	3	31	Manure	Dry Manure	1120.8	kg/ha
3	4	14	Manure	Dry Manure	1120.8	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	MB Plow		

309 - Cg-Cs-O/A-A-A-A (LQ) Fall MB Plow -10,000 ga/acre/yr

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	1675	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	12	Manure	Liquid	5,582	kg/ha
1	11	15	Tillage	MB Plow		
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	15	Manure	Liquid	5,582	kg/ha
2	10	18	Tillage	MB Plow		
3	4	14	Manure	Liquid	1,675	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	MB Plow		

310 - Cg-Cs-O/A-A-A-A (DH) Fall MB Plow - 25 tons/acre/year

Year	Month	Day	Operation	Type	Amount	Unit
1	1	31	Manure	Dry Weight	3362.5	kg/ha
1	2	28	Manure	Dry Weight	3,363	kg/ha
1	3	31	Manure	Dry Weight	3,363	kg/ha
1	4	29	Manure	Dry Weight	3,363	kg/ha
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	15	Tillage	MB Plow		
2	1	31	Manure	Dry Weight	3362.5	kg/ha
2	2	28	Manure	Dry Weight	3,363	kg/ha
2	3	31	Manure	Dry Weight	3,363	kg/ha
2	4	29	Manure	Dry Weight	3,363	kg/ha
2	5	1	Tillage	Cultivation		
2	5	15	Plant	Corn Silage		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	9	15	Harvest	Corn Silage		
2	10	1	Tillage	MB Plow		
3	1	31	Manure	Dry Manure	1120.8	kg/ha
3	2	28	Manure	Dry Manure	1120.8	kg/ha
3	3	31	Manure	Dry Manure	1120.8	kg/ha
3	4	14	Manure	Dry Manure	1120.8	kg/ha
3	4	17	Tillage	Cultivation		
3	4	25	Plant	Alfalfa		
3	8	10	Harvest	Alfalfa		
4	6	1	Harvest	Alfalfa		
4	7	15	Harvest	Alfalfa		
4	8	30	Harvest	Alfalfa		
5	6	1	Harvest	Alfalfa		
5	7	15	Harvest	Alfalfa		
5	8	30	Harvest	Alfalfa		
6	6	1	Harvest	Alfalfa		
6	7	15	Harvest	Alfalfa		
6	8	30	Harvest	Alfalfa		
6	10	15	Tillage	MB Plow		

400 - Cg-Cg-So-Cg-Cg-So (Fall Chisel/Spring Disk)

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Disk Plow		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	20	Tillage	Chisel Plow		
2	5	1	Tillage	Disk Plow		
2	5	15	Plant	Corn Grain		
2	5	15	Fertilizer	20:10:18	168	kg/ha
2	11	1	Harvest	Corn Grain		
2	11	20	Tillage	Chisel Plow		
3	5	1	Tillage	Disk Plow		
3	5	30	Plant	Soybean		
3	10	25	Harvest	Soybean		
3	11	1	Tillage	Chisel Plow		
4	5	1	Tillage	Disk Plow		
4	5	15	Plant	Corn Grain		
4	5	15	Fertilizer	20:10:18	168	kg/ha
4	11	1	Harvest	Corn Grain		
4	11	20	Tillage	Chisel Plow		
5	5	1	Tillage	Disk Plow		
5	5	15	Plant	Corn Grain		
5	5	15	Fertilizer	20:10:18	168	kg/ha
5	11	1	Harvest	Corn Grain		
5	11	20	Tillage	Chisel Plow		
6	5	1	Tillage	Disk Plow		
6	5	30	Plant	Soybean		
6	10	25	Harvest	Soybean		
6	11	1	Tillage	Chisel Plow		

401 - Cg-So-Cg-So-Cg-So (Fall Chisel/Spring Disk)

Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Disk Plow		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
1	11	20	Tillage	Chisel Plow		
2	5	1	Tillage	Disk Plow		
2	5	30	Plant	Soybean		
2	10	25	Harvest	Soybean		
2	11	1	Tillage	Chisel Plow		
3	5	1	Tillage	Disk Plow		
3	5	15	Plant	Corn Grain		
3	5	15	Fertilizer	20:10:18	168	kg/ha
3	11	1	Harvest	Corn Grain		
3	11	20	Tillage	Chisel Plow		
4	5	1	Tillage	Disk Plow		
4	5	30	Plant	Soybean		
4	10	25	Harvest	Soybean		
4	11	1	Tillage	Chisel Plow		
5	5	1	Tillage	Disk Plow		
5	5	15	Plant	Corn Grain		
5	5	15	Fertilizer	20:10:18	168	kg/ha
5	11	1	Harvest	Corn Grain		
5	11	20	Tillage	Chisel Plow		
6	5	1	Tillage	Disk Plow		
6	5	30	Plant	Soybean		
6	10	25	Harvest	Soybean		
6	11	1	Tillage	Chisel Plow		

402 - Cg-So-Cg-So-Cg-So (No Till All Years)

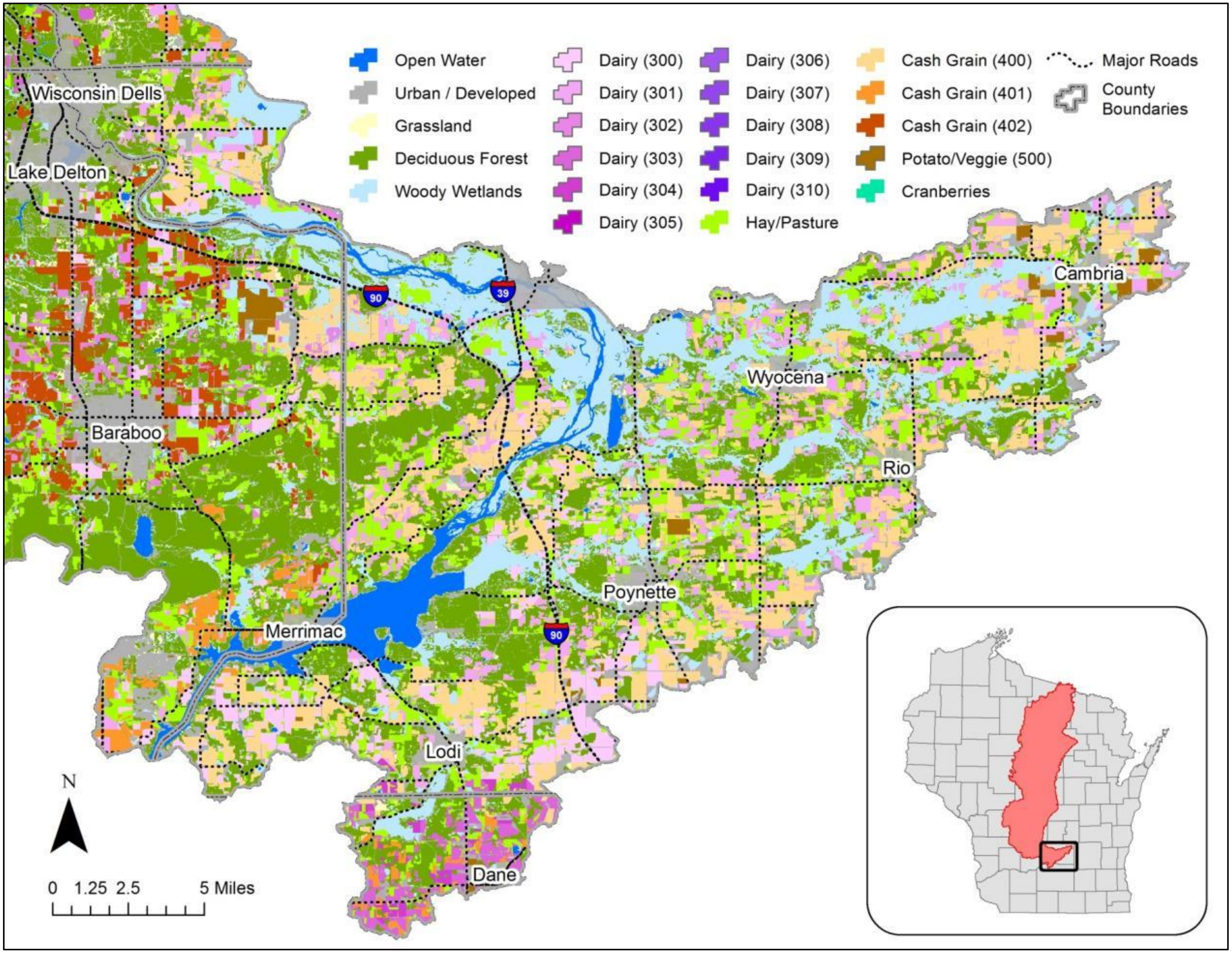
Year	Month	Day	Operation	Type	Amount	Unit
1	5	1	Tillage	Cultivation		
1	5	15	Plant	Corn Grain		
1	5	15	Fertilizer	20:10:18	168	kg/ha
1	11	1	Harvest	Corn Grain		
2	5	1	Tillage	Cultivation		
2	5	30	Plant	Soybean		
2	10	25	Harvest	Soybean		
3	5	15	Plant	Corn Grain		
3	5	15	Fertilizer	20:10:18	168	kg/ha
3	11	1	Harvest	Corn Grain		
4	5	1	Tillage	Cultivation		
4	5	30	Plant	Soybean		
4	10	25	Harvest	Soybean		
5	5	15	Plant	Corn Grain		
5	5	15	Fertilizer	20:10:18	168	kg/ha
5	11	1	Harvest	Corn Grain		
6	5	1	Tillage	Cultivation		
6	5	30	Plant	Soybean		
6	10	25	Harvest	Soybean		

500 - Po-Vg-Vg-Po-Vg-Vg

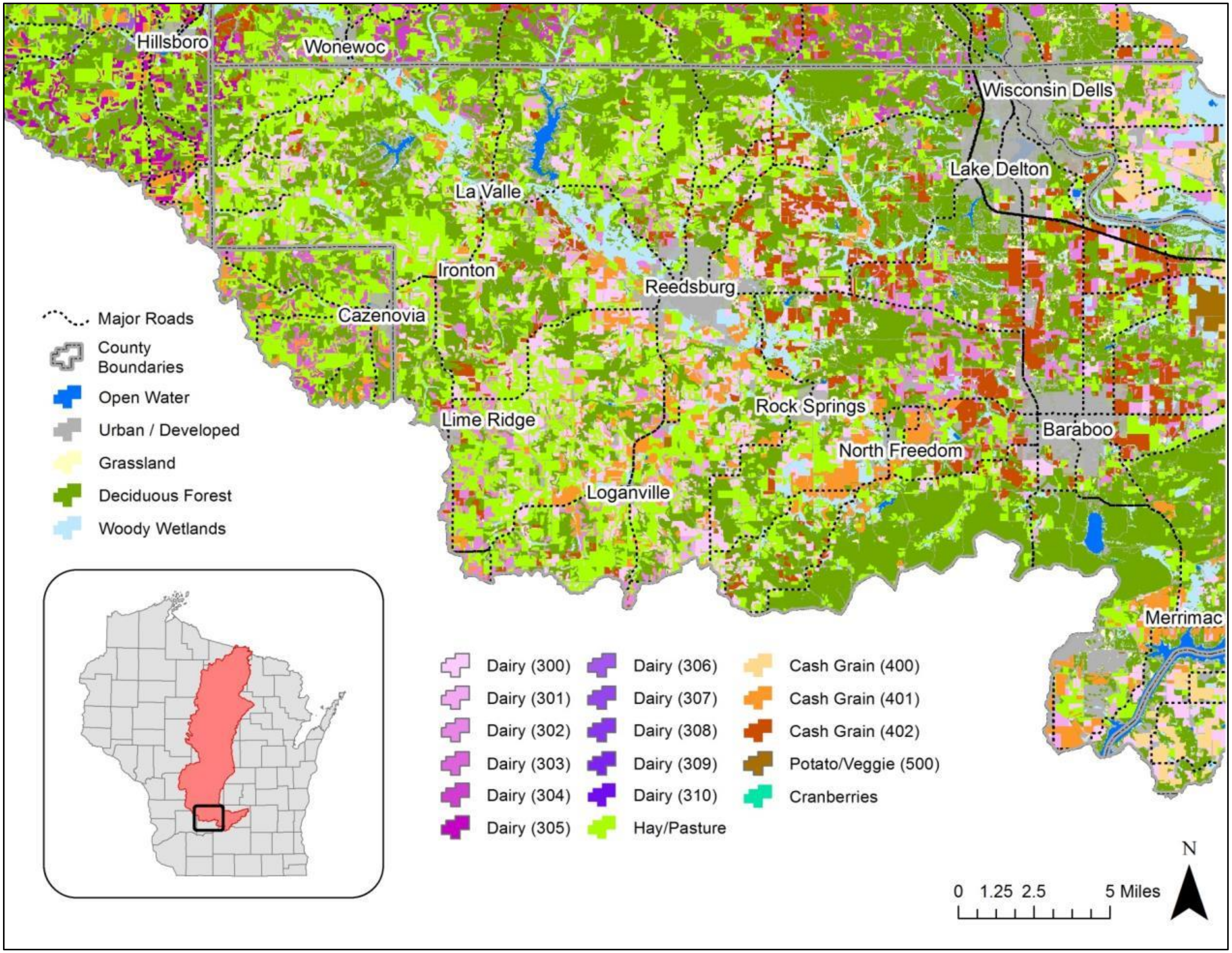
Year	Month	Day	Operation	Type	Amount	Unit
1	4	30	Tillage	MB Plow		
1	4	30	Plant	Potato		
1	4	30	Fertilizer	20:10:18	280	kg/ha
1	6	1	Tillage	Mounding		
1	6	15	Fertilizer	18:46:00	112	kg/ha
1	8	20	Harvest	Potato		
2	5	15	Tillage	Cultivator		
2	5	20	Plant	Snap Beans		
2	5	20	Fertilizer	20:10:18	168	kg/ha
2	7	15	Harvest	Snap Beans		
3	5	15	Tillage	Cultivator		
3	5	20	Plant	Sweet Corn		
3	5	20	Fertilizer	20:10:18	168	kg/ha
3	6	1	Fertilizer	18:46:00	168	kg/ha
3	8	30	Harvest	Sweet Corn		
4	4	30	Tillage	MB Plow		
4	4	30	Plant	Potato		
4	4	30	Fertilizer	20:10:18	280	kg/ha
4	6	1	Tillage	Mounding		
4	6	15	Fertilizer	18:46:00	112	kg/ha
4	8	20	Harvest	Potato		
5	5	15	Tillage	Cultivator		
5	5	20	Plant	Snap Beans		
5	5	20	Fertilizer	20:10:18	168	kg/ha
5	7	15	Harvest	Snap Beans		
6	5	15	Tillage	Cultivator		
6	5	20	Plant	Sweet Corn		
6	5	20	Fertilizer	20:10:18	168	kg/ha
6	6	15	Fertilizer	18:46:00	168	kg/ha
6	8	30	Harvest	Sweet Corn		

Appendix D

SWAT Integrated Crop Rotations per Region



Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Major Roads
County Boundaries
Wisconsin Dells
Lake Delton
Baraboo
Merrimac
Lodi
Dane
Poynette
Wyocena
Rio
Cambria
90
39
N
0 1.25 2.5 5 Miles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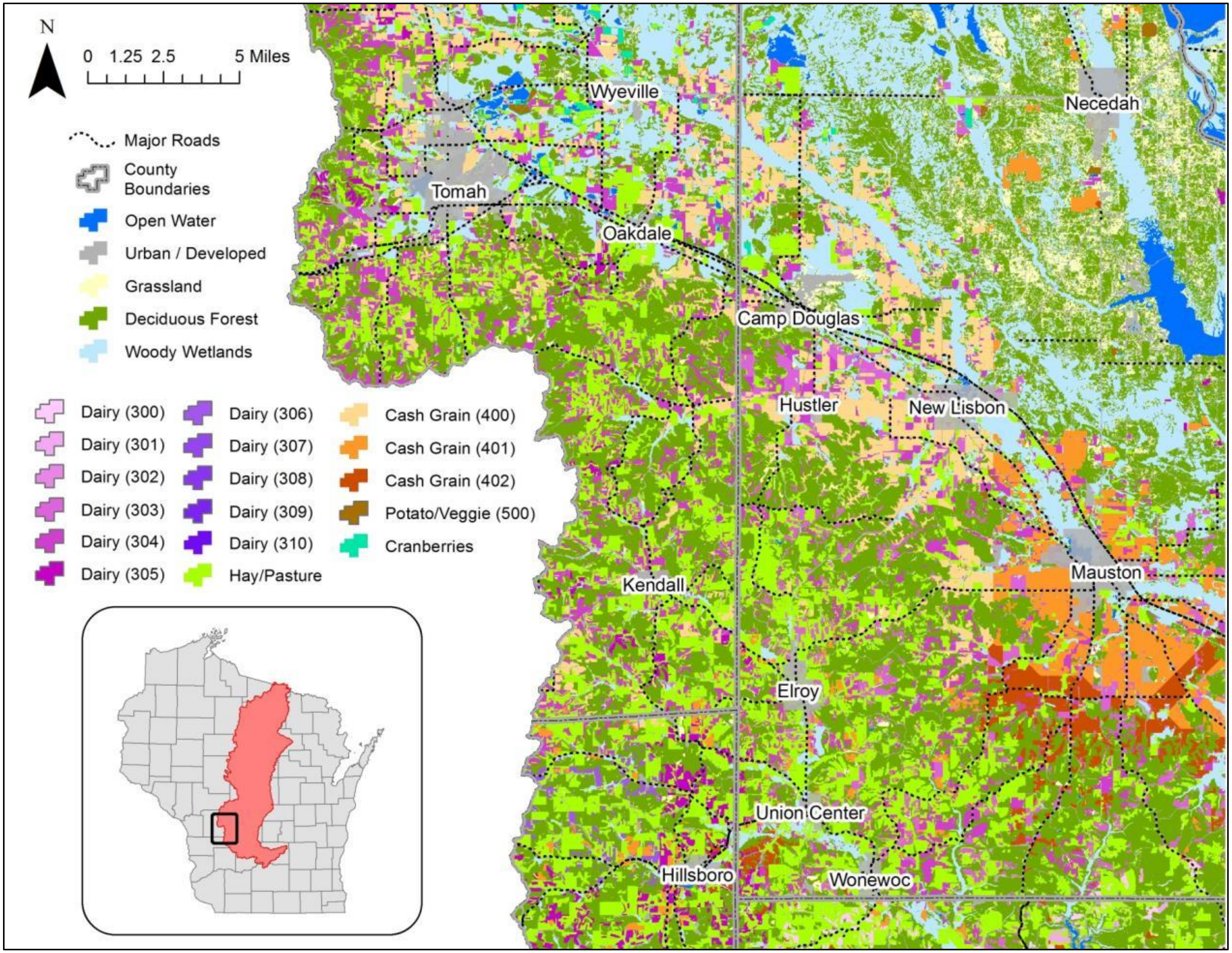
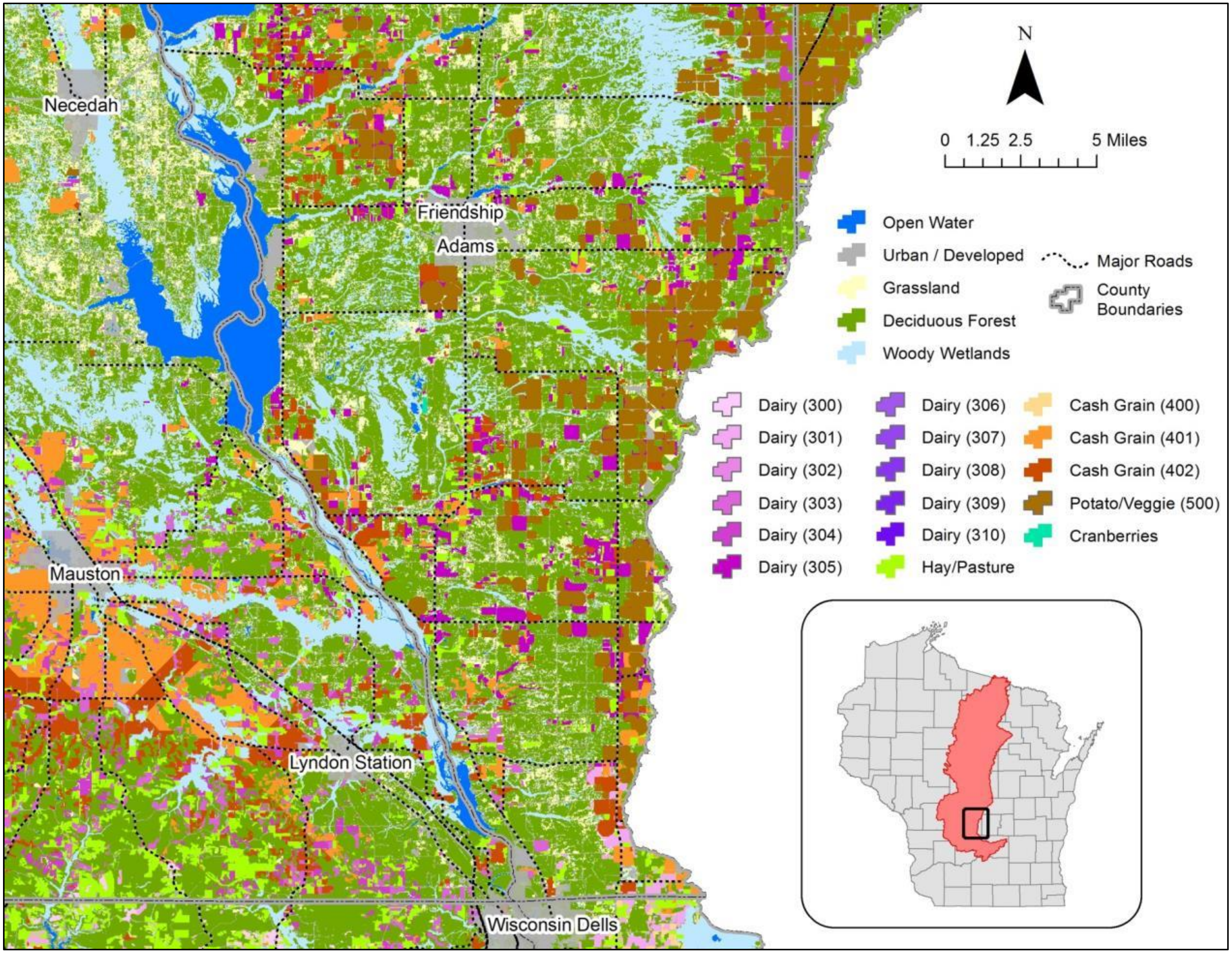
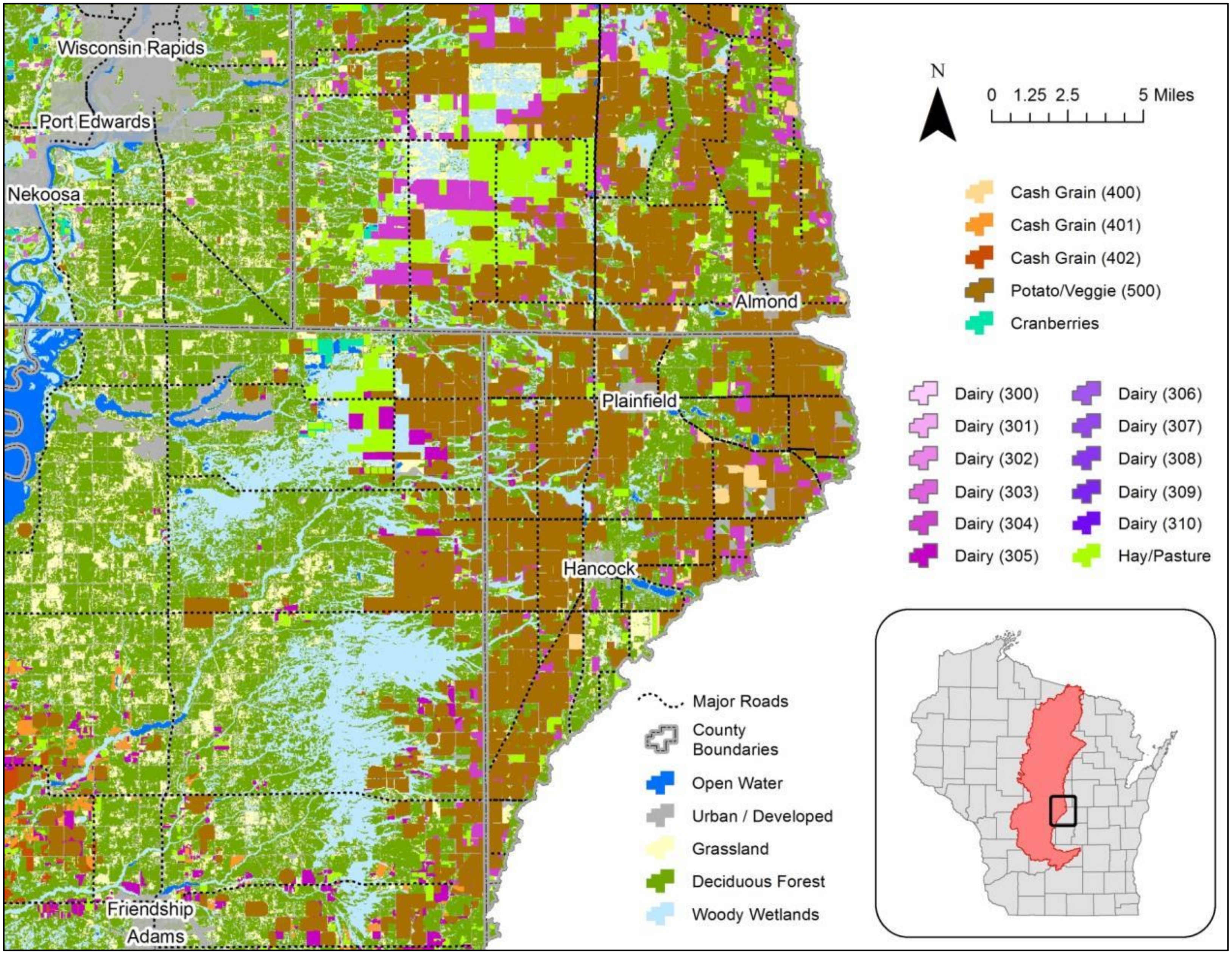
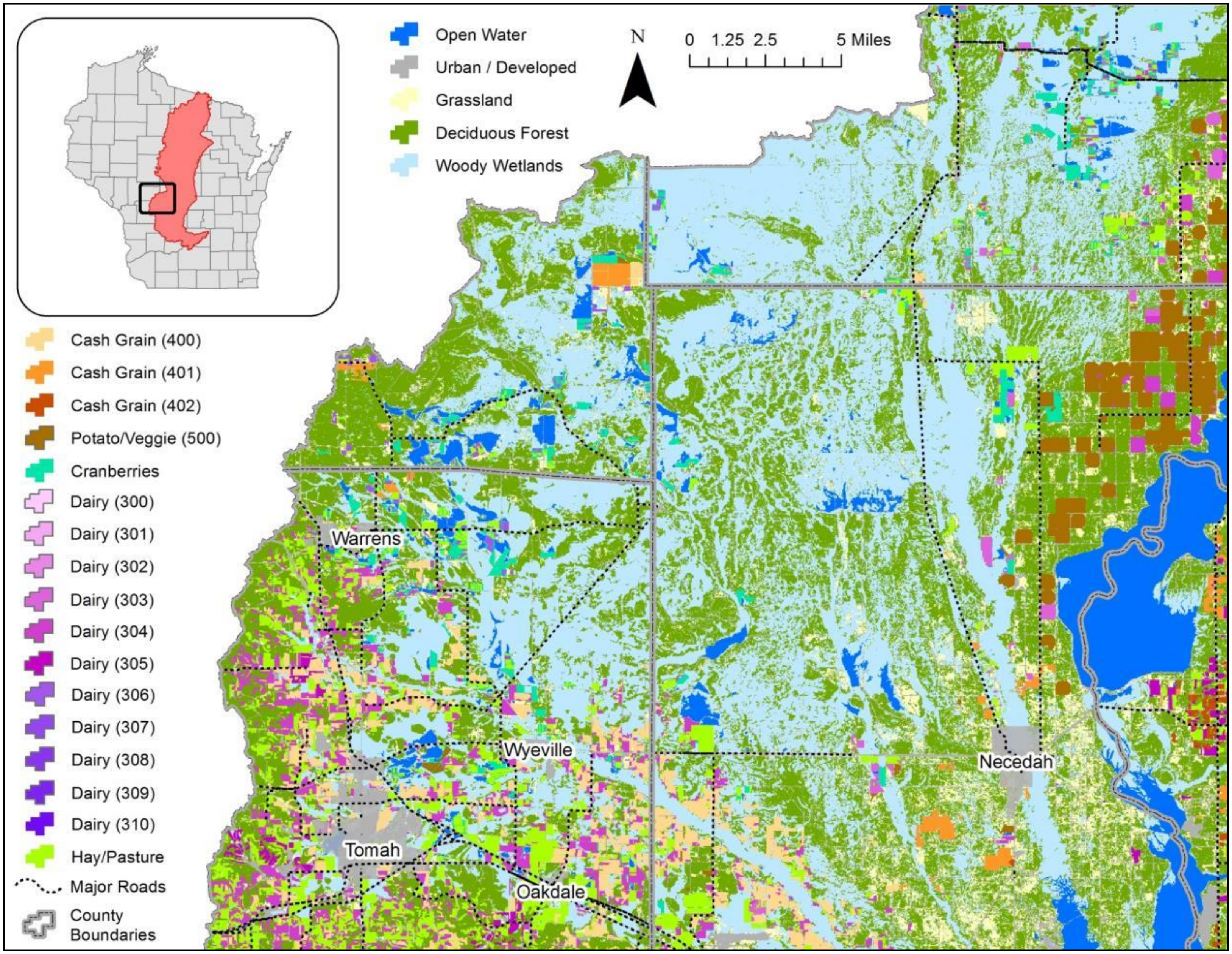
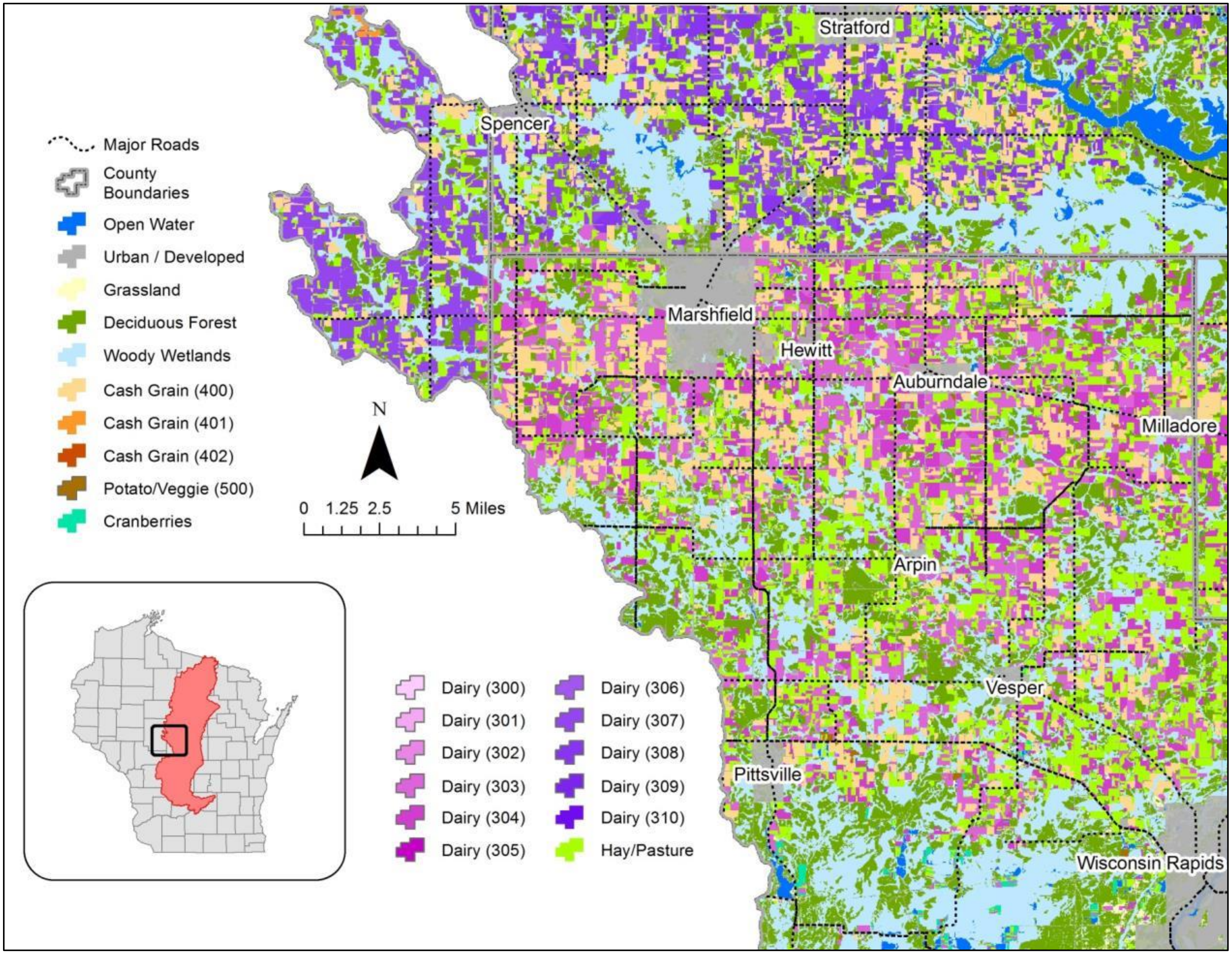
Wonewoc
Wisconsin Dells
Lake Delton
La Valle
Ironton
Reedsburg
Cazenovia
Lime Ridge
Rock Springs
Baraboo
North Freedom
Loganville
Merrimac
Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
N
0 1.25 2.5 5 Miles


N
0 1.25 2.5 5 Miles
Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Wyeville
Necedah
Tomah
Oakdale
Camp Douglas
Hustler
New Lisbon
Mauston
Kendall
Elroy
Union Center
Hillsboro
Wonewoc


Necedah
Friendship
Adams
Mauston
Lyndon Station
Wisconsin Dells
N
0 1.25 2.5 5 Miles
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Major Roads
County Boundaries
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries


Wisconsin Rapids
Port Edwards
Nekoosa
Almond
Plainfield
Hancock
Friendship
Adams
N
0 1.25 2.5 5 Miles
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands


Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
N
0 1.25 2.5 5 Miles
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Major Roads
County Boundaries
Warrens
Wyeville
Necedah
Tomah
Oakdale



Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
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Dairy (310)
Hay/Pasture
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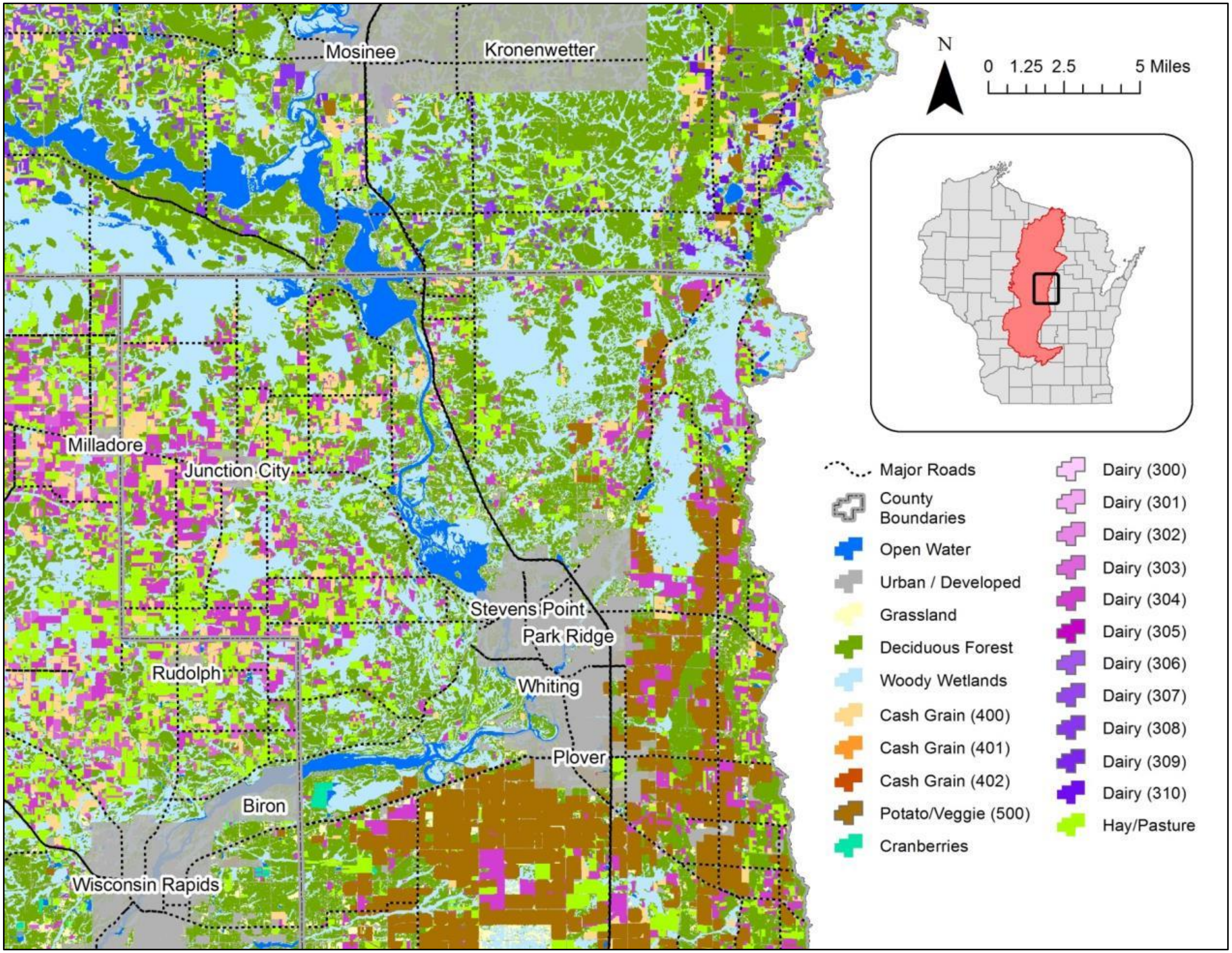
Stratford
Spencer
Marshfield
Hewitt
Auburndale
Milladore
Arpin
Vesper
Pittsville
Wisconsin Rapids


Mosinee
Kronenwetter
Milladore
Junction City
Stevens Point
Park Ridge
Rudolph
Whiting
Plover
Biron
Wisconsin Rapids
N
0 1.25 2.5 5 Miles
Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Dairy (300)
Dairy (301)
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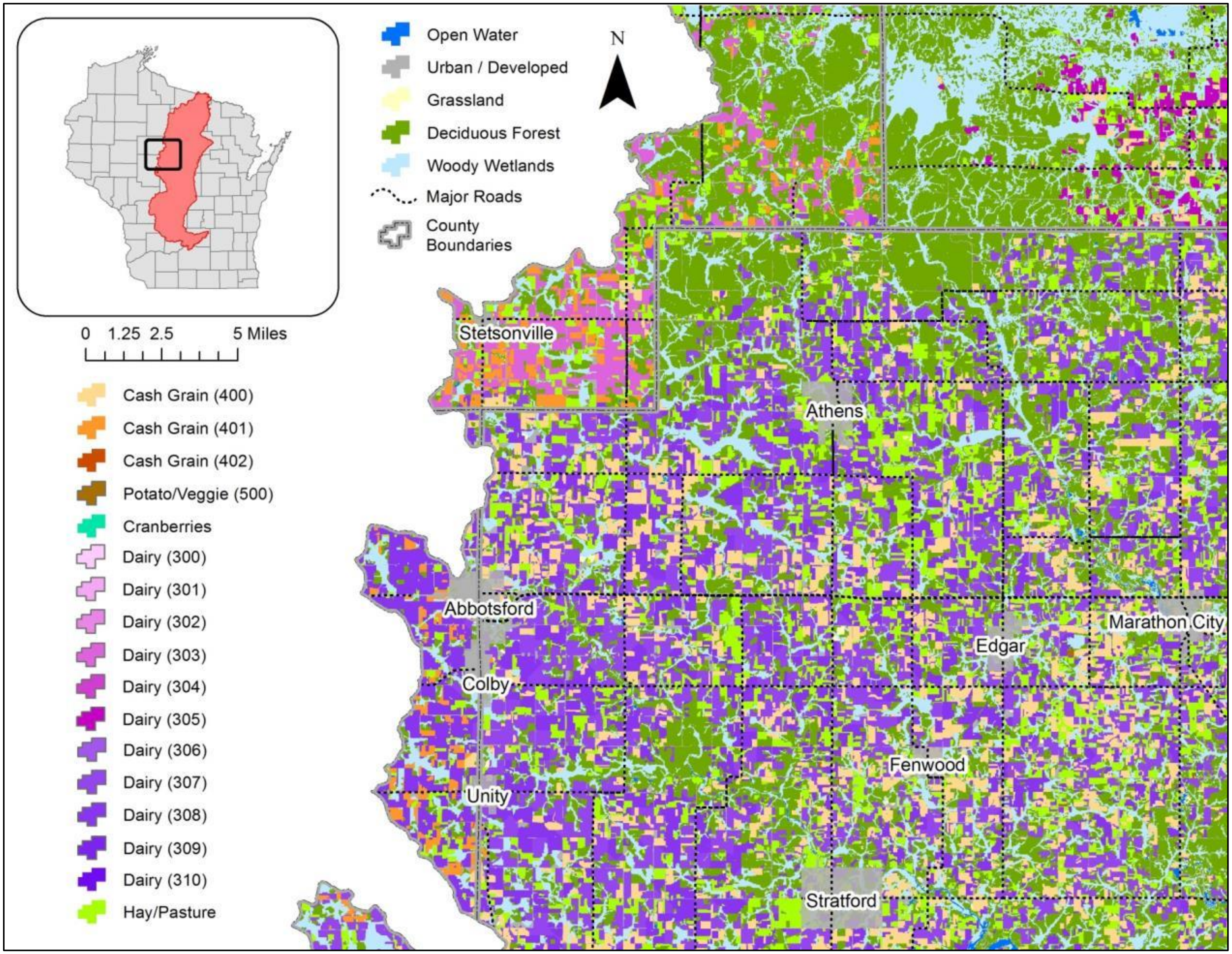
Dairy (310)
Hay/Pasture


Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Major Roads
County Boundaries
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Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
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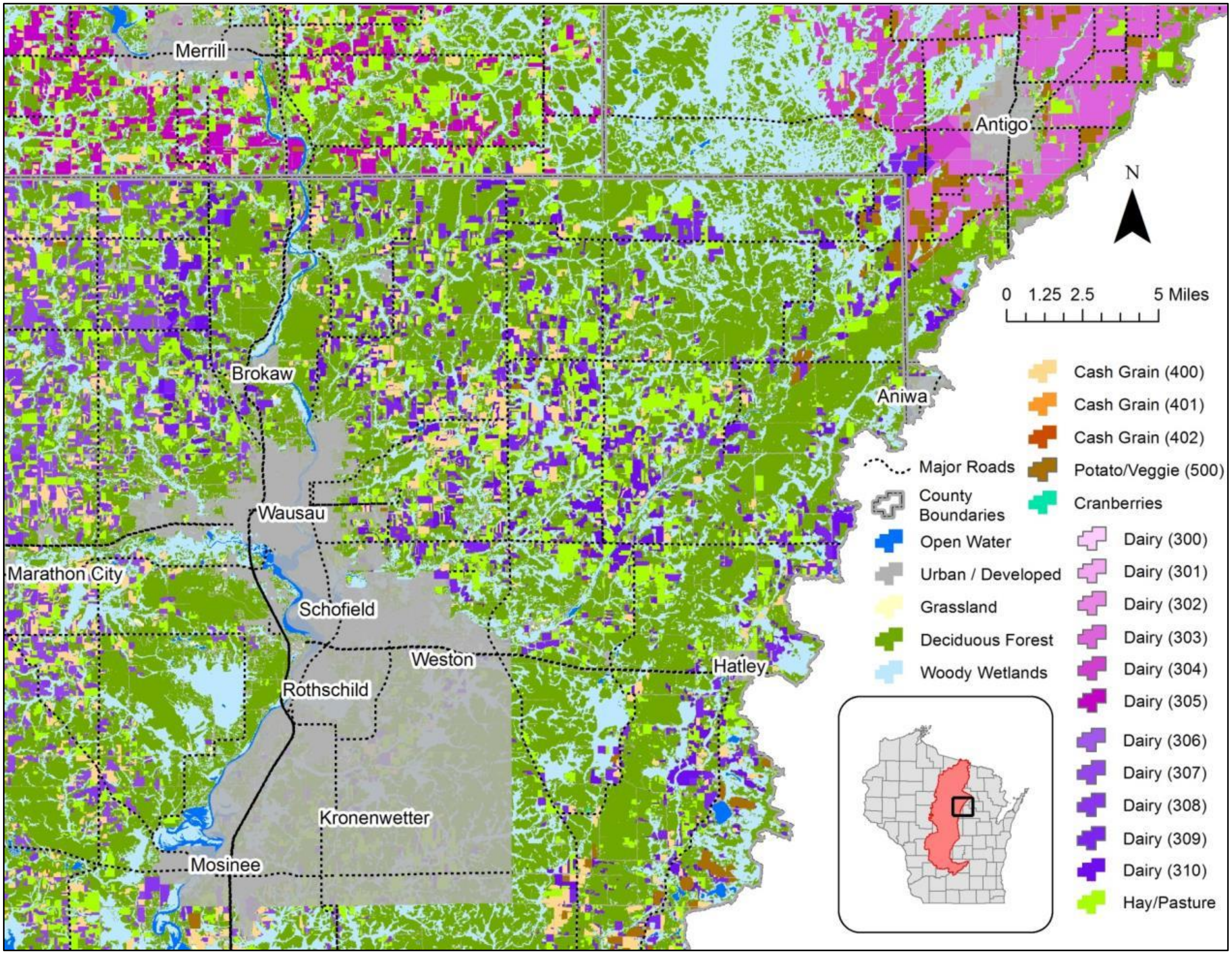
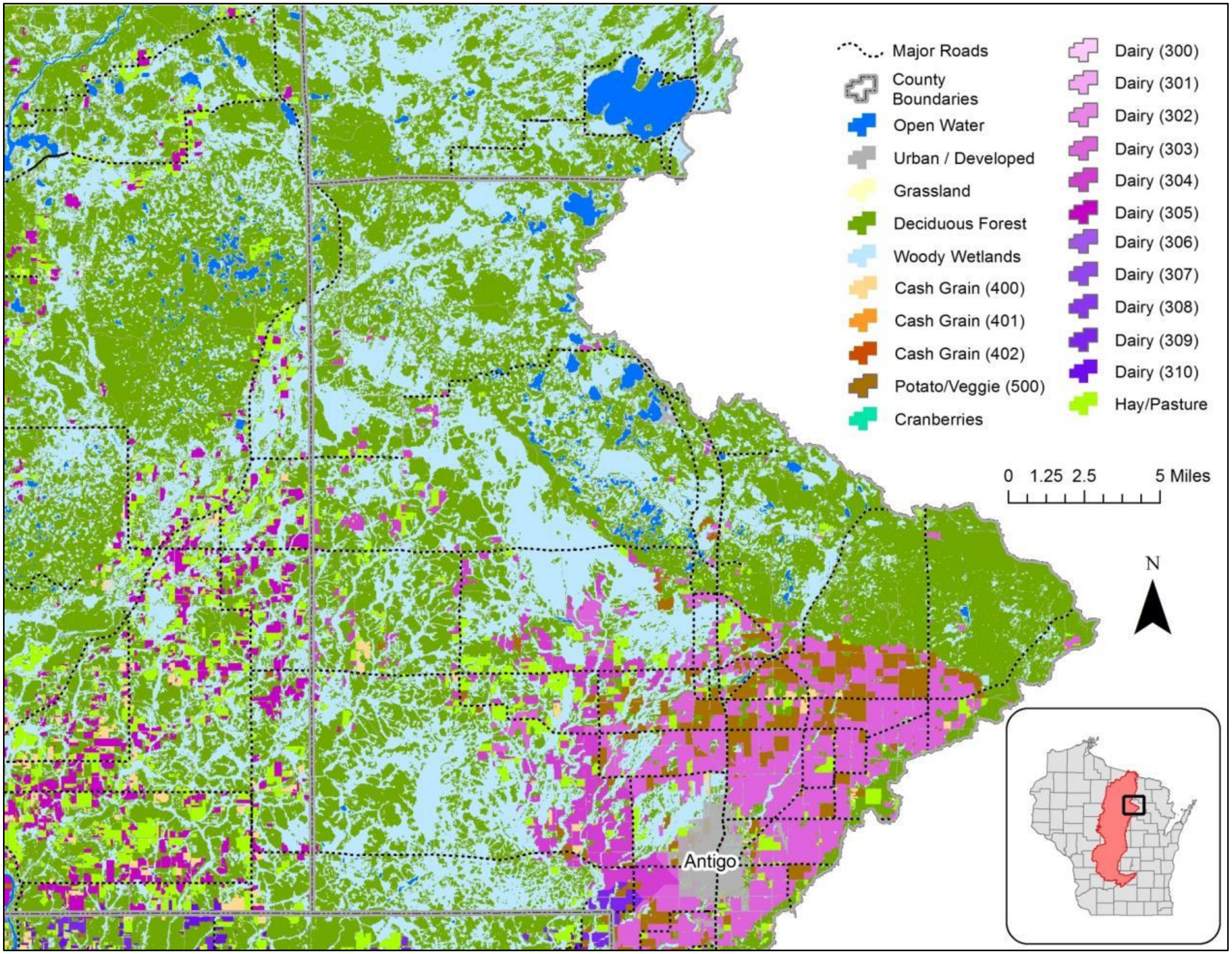
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Stetsonville
Athens
Abbotsford
Colby
Unity
Edgar
Marathon City
Fenwood
Stratford



Merrill
Antigo
N
0 1.25 2.5 5 Miles
Brokaw
Aniwa
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
Dairy (304)
Dairy (305)
Dairy (306)
Dairy (307)
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
Wausau
Marathon City
Schofield
Weston
Hatley
Rothschild
Kronenwetter
Mosinee


Major Roads
County Boundaries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Cash Grain (400)
Cash Grain (401)
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Potato/Veggie (500)
Cranberries
Dairy (300)
Dairy (301)
Dairy (302)
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Dairy (304)
Dairy (305)
Dairy (306)
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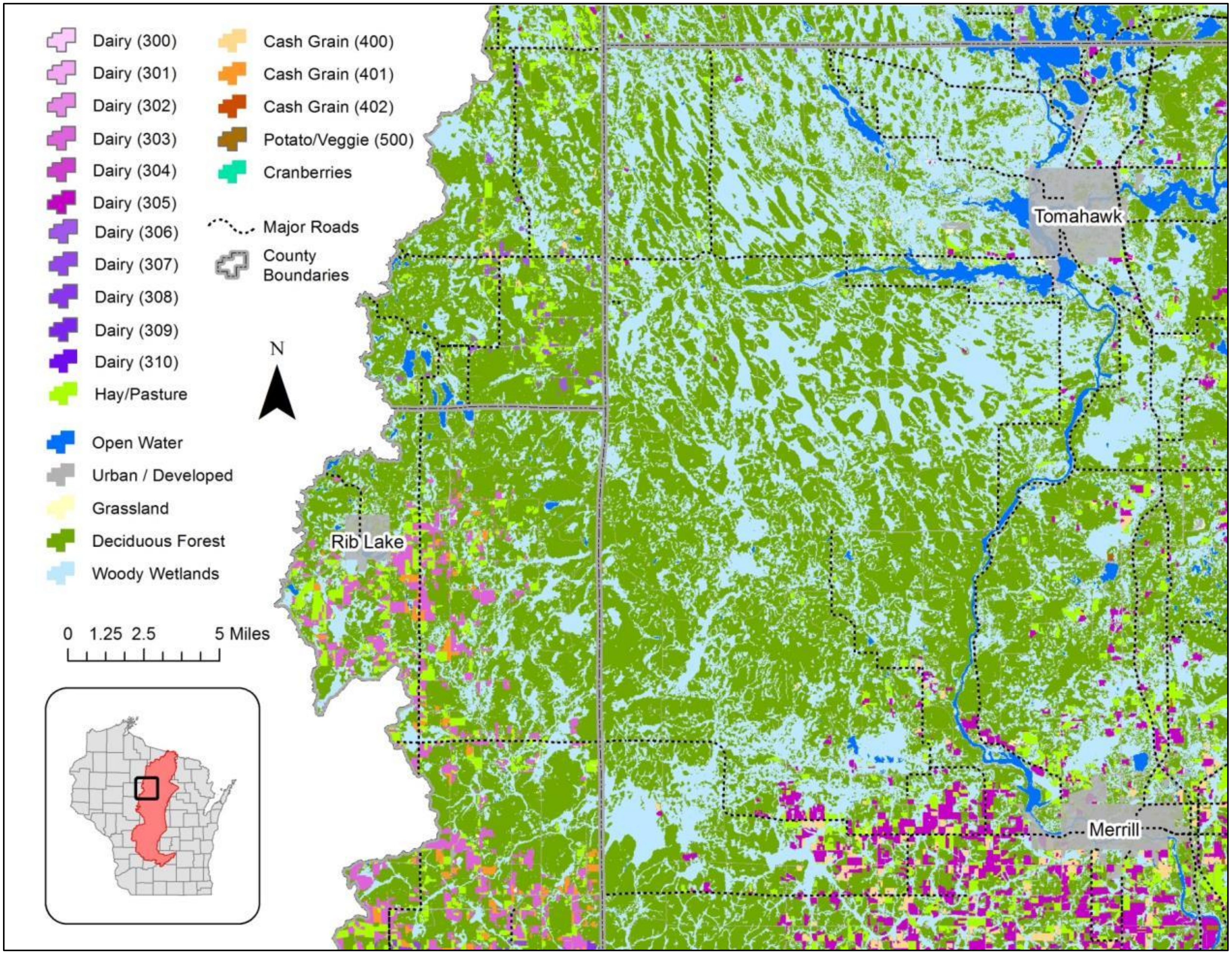
Dairy (308)
Dairy (309)
Dairy (310)
Hay/Pasture
0 1.25 2.5 5 Miles
N
Antigo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Dairy (307)
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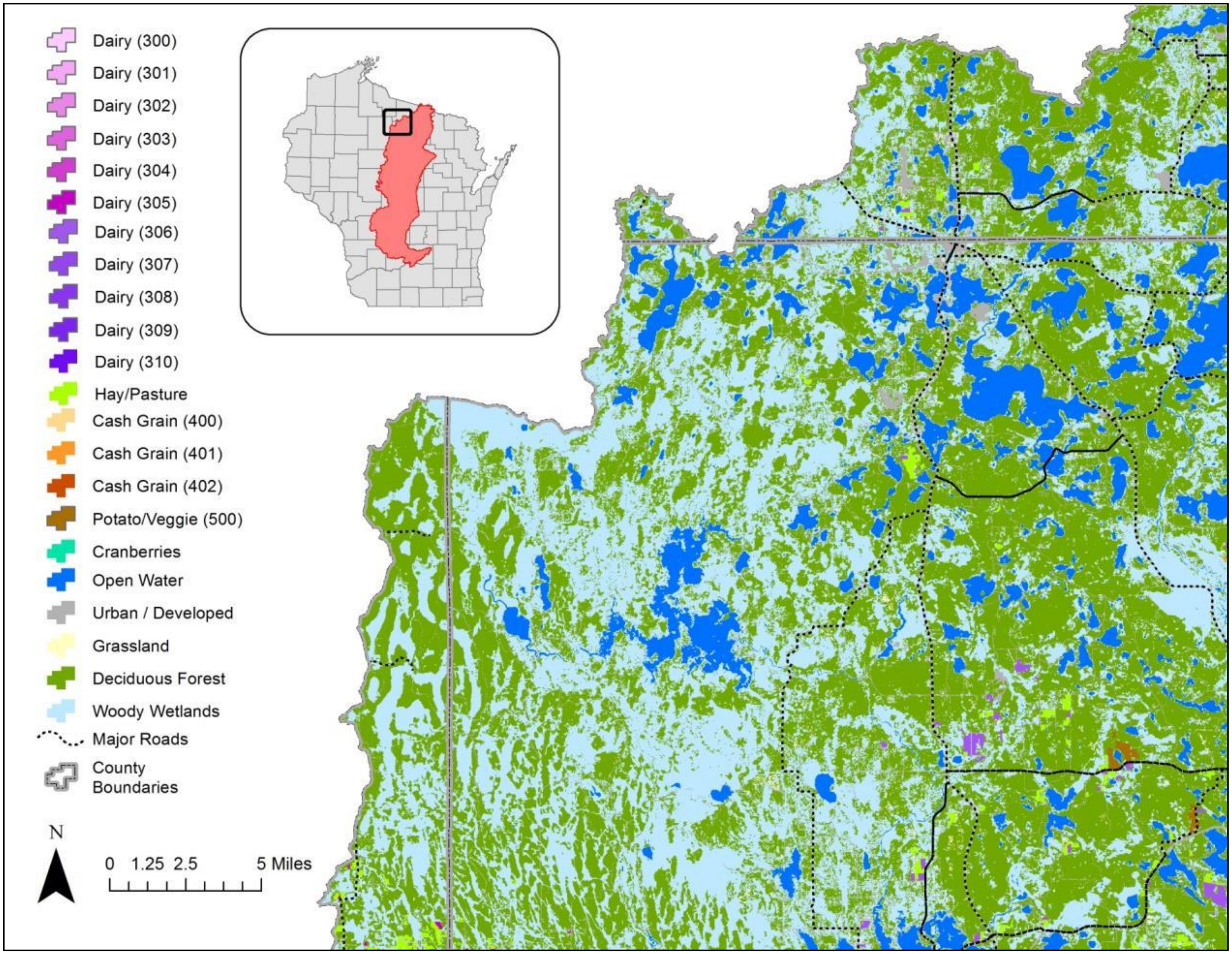
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Major Roads
County Boundaries
N
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
0 1.25 2.5 5 Miles
Tomahawk
Rib Lake
Merrill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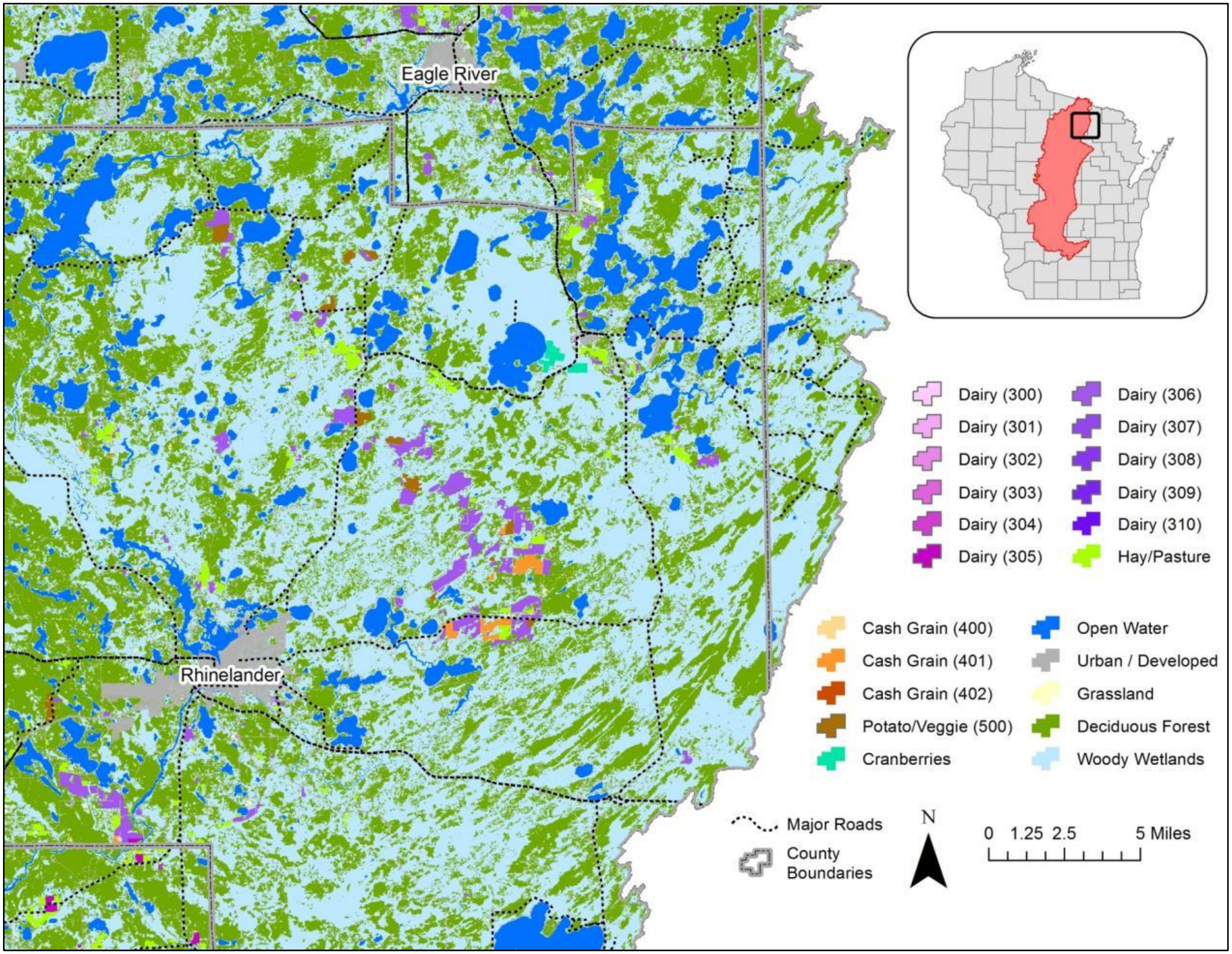
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Major Roads
County Boundaries
N
0 1.25 2.5 5 Miles



Eagle River
Rhinelander
Dairy (300)
Dairy (301)
Dairy (302)
Dairy (303)
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Dairy (306)
Dairy (307)
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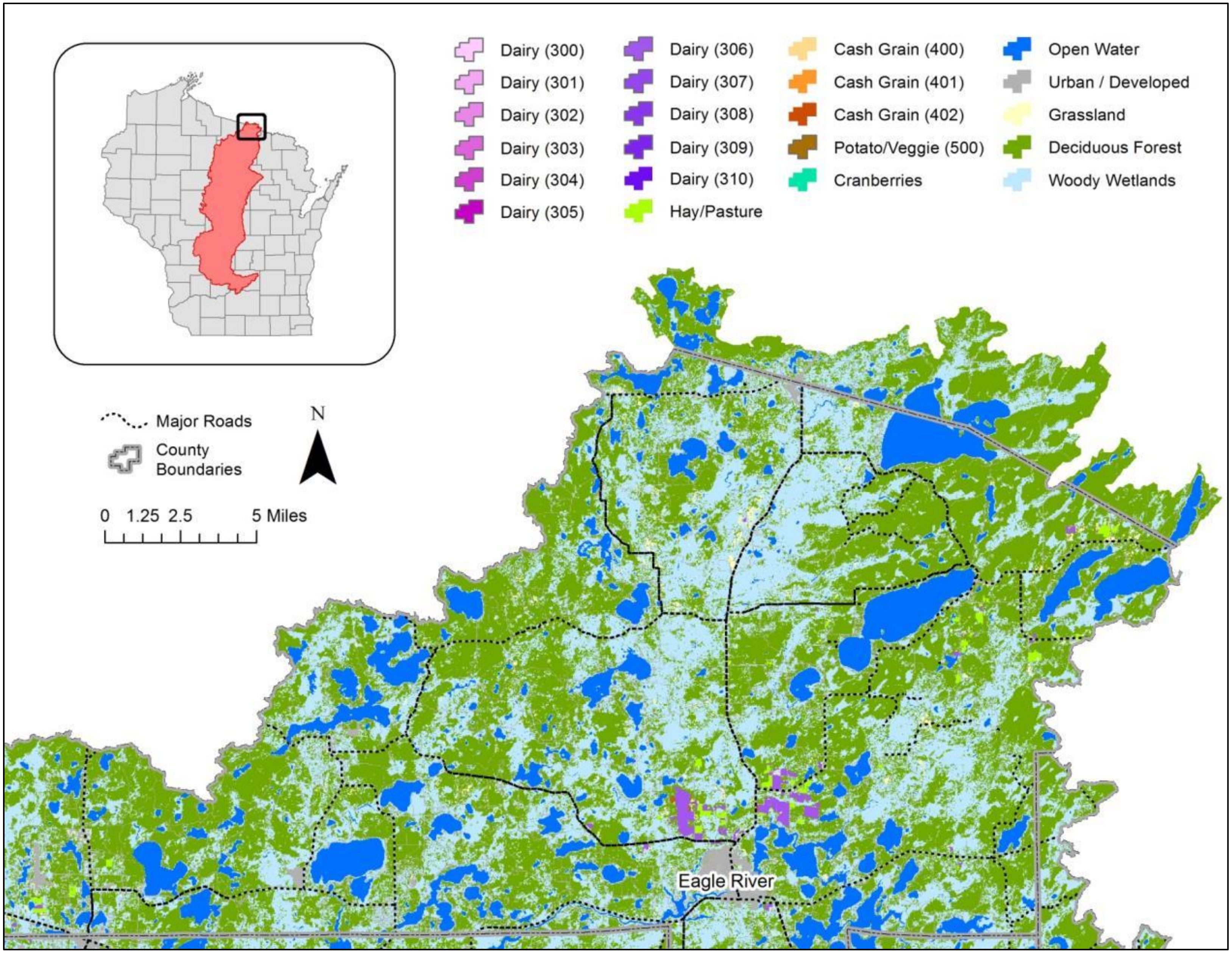
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Major Roads
County Boundaries
N
0 1.25 2.5 5 Miles


Dairy (300)
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Dairy (309)
Dairy (310)
Hay/Pasture
Cash Grain (400)
Cash Grain (401)
Cash Grain (402)
Potato/Veggie (500)
Cranberries
Open Water
Urban / Developed
Grassland
Deciduous Forest
Woody Wetlands
Major Roads
County Boundaries
N
0 1.25 2.5 5 Miles
Eagle River

Appendix E

Manure Estimation Tables by County (Major Counties)

MARATHON COUNTY

CDL Dairy Acres	230,306
% Daily Haul Acres	0.40
% Storage Acres	0.60
% 6-Year Rotation Receiving Manure (corn years)	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	139,500
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	6,428,160,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	2,579,422,346
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	1,590,379,696
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	4,169,802,042
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	6,600
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	3,300
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	36,962,361
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	31,707,370
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	68,669,731
GRAZED LANDS ESTIMATE	
Land Area (Acres)	12,349
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	853,562,880
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**6,428,160,000**
CDL Dry Weight (lbs/6-year rotation)	**5,092,034,653**

JUNEAU COUNTY

CDL Dairy Acres	35,951
% Daily Haul Acres	0.50
% Storage Acres	0.50
% 6-Year Rotation Receiving Manure	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	28,000
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	1,290,240,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	503,307,220
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	206,880,838
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	710,188,058
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	1,977
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	989
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	13,840,388
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	7,915,120
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	21,755,508
GRAZED LANDS ESTIMATE	
Land Area (Acres)	7,500
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	518,400,000
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**1,290,240,000**
CDL Dry Weight (lbs/6-year rotation)	**1,250,343,566**

LINCOLN COUNTY

CDL Dairy Acres	26,551
% Daily Haul Acres	0.33
% Storage Acres	0.67
% 6-Year Rotation Receiving Manure	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	12,500
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	576,000,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	247,813,598
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	203,724,019
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	451,537,617
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	889
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	444
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	4,147,213
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	4,743,463
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	8,890,676
GRAZED LANDS ESTIMATE	
Land Area (Acres)	1,000
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	69,120,000
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**576,000,000**
CDL Dry Weight (lbs/6-year rotation)	**529,548,293**

SAUK COUNTY

CDL Dairy Acres	84,694
% Daily Haul Acres	0.85
% Storage Acres	0.15
% 6-Year Rotation Receiving Manure	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	82,000
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	3,778,560,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	2,015,718,453
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	146,214,119
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	2,161,932,572
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	16,223
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	8,111
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	193,052,662
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	19,483,069
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	212,535,731
GRAZED LANDS ESTIMATE	
Land Area (Acres)	5,000
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	345,600,000
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**3,778,560,000**
CDL Dry Weight (lbs/6-year rotation)	**2,720,068,303**

ADAMS COUNTY

CDL Dairy Acres	23,507
% Daily Haul Acres	0.40
% Storage Acres	0.60
% 6-Year Rotation Receiving Manure	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	11,000
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	506,880,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	263,274,523
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	162,325,668
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	425,600,192
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	3,369
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	1,685
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	18,869,195
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	16,186,534
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	35,055,729
GRAZED LANDS ESTIMATE	
Land Area (Acres)	500
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	34,560,000
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**506,880,000**
CDL Dry Weight (lbs/6-year rotation)	**495,215,921**

WOOD COUNTY

CDL Dairy Acres	72,992
% Daily Haul Acres	0.40
% Storage Acres	0.60
% 6-Year Rotation Receiving Manure	0.33
% Dry (Liquid)	0.06
% Dry (Solid)	0.24
Pounds manure per gallon liquid	8.34
Storage Application Rate - Corn Years (ga/acre/yr)	10,000
Storage Application Rate - 1st Year Alfalfa (ga/acre/yr)	3,000
DH Application Rate - Corn Years (tons/acre/yr)	25
DH Application Rate - 1st Year Alfalfa (tons/acre/yr	8
Cattle Census 2010 (head cattle)	45,500
Avg. manure output per year (tons/cow)	16
Census Dry Weight Output (lbs/6-year rotation)	2,096,640,000
FROM DAIRY CDL PIXELS	
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	817,513,998
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	504,049,934
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	1,321,563,932
FROM CONTINUOUS CORN CDL PIXELS	
Total Continuous Corn (Acres)	3,275
% Cont. Corn Assumed to be Dairy (Acres)	0.50
Dairy from Cont. Corn pixels (Acres)	1,637
CDL Rotation Dry Weight Total from DH (lbs/6-year rotation)	18,337,405
CDL Rotation Dry Weight Total from Storage (lbs/6-year rotation)	15,730,350
CDL Rotation Dry Wright Total from DH & Storage (lbs/6-year rotation)	34,067,755
FROM MANAGED GRAZED LANDS	
GRAZED LANDS ESTIMATE (Acres)	3,000
Dry Weight Output - Assuming 1.5 cows per acre (lbs/6-year rotation)	207,360,000
RESULTS	
NASS Census Dry Weight (lbs/6-year rotation)	**2,096,640,000**
CDL Dry Weight (lbs/6-year rotation)	**1,562,991,687**